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Water Quality Conditions in the Missouri River Mainstem System

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2010 Report

Water Quality Conditions in the Missouri River Mainstem System

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TABLE OF CONTENTS

Page

List of Tables

List of Figures

List of Plates

EXECUTIVE SUMMARY

Omaha District Water Quality Management Program

The Omaha District (District) of the U.S. Army Corps of Engineers (Corps) is implementing a Water Quality Management Program (WQMP) as part of the operation and maintenance activities associated with managing the Corps' civil works projects in the District. The WQMP addresses surface water quality management issues and adheres to the guidance and requirements specified in the Corps' Engineering Regulation – ER 1110-2-8154, "Water Quality and Environmental Management for Corps Civil Works Projects" (USACE, 1995).

A periodic report of water quality conditions in the Missouri River Mainstem System (Mainstem System) is currently being prepared annually to document and assess water quality conditions occurring at the Corps' Mainstem System projects in the District. The report describes existing water quality conditions and identifies any evident surface water quality management concerns. The annual reporting of Mainstem System project water quality conditions is done to facilitate water quality management decisions regarding the operation and regulation of the Mainstem System projects.

General Water Quality Concerns in the Omaha District

The following general water quality concerns have been identified for civil works projects in the District: 1) reservoir eutrophication and hypolimnetic dissolved oxygen depletion, 2) sedimentation, 3) shoreline erosion, 4) bioaccumulation of contaminants in aquatic organisms, 5) occurrence of pesticides, and 6) urbanization.

Prioritization of District-Wide Water Quality Management Issues

The District has identified eight priority issues for water quality management; these priority issues are listed in Table 1-2.

Summary of Project-Specific TMDL Considerations, Fish Consumption Advisories, and Other Water Quality Management Issues

Table 1-3 summarizes TMDL considerations, fish consumption advisories, and other water quality management issues applicable to the Mainstem System projects. The impaired uses and pollutant/stressors (i.e., TMDL considerations) and identified contamination (i.e., Fish Consumption Advisories) identified in Table 1-3 are taken directly from the latest State 303(d) impaired waters listings and issued fish consumption advisories. They are provided for information purposes and are not based on water quality monitoring conducted by the District. The listed other water quality management issues in Table 1-3 were identified by the District based on water quality monitoring and Corps water quality management concerns. Water quality management issues at specific Mainstem System projects will be assessed in further detail in water quality reports that will be prepared for the project by the District.

Limnological Processes in Reservoirs

The Mainstem System projects in the District involve the operation and maintenance of reservoirs and the regulation of flows discharged from the reservoirs. Much of the water quality monitoring conducted by the District is done to determine existing water quality conditions and identify water quality management concerns at these reservoirs. A basic understanding of the limnological processes that occur in reservoirs is needed to interpret the water quality information provided in this report. Chapter 2 of this report provides a basic overview of limnological processes that occur in reservoirs.

Water Quality Monitoring at the Mainstem System Reservoirs

Long-term, fixed-station ambient water quality monitoring has occurred at the six Mainstem System reservoirs (i.e., Fort Peck, Garrison, Oahe, Big Bend, Fort Randall, and Gavins Point) for the past 30 years. Recent ambient monitoring conducted by the District at the Mainstem System reservoirs included monthly (i.e., May through September) water quality monitoring at a near-dam, deepwater site. At Garrison, Fort Peck, Oahe, and Fort Randall Reservoirs, additional long-term ambient sites were respectively added in 2006, 2007, 2008, and 2009. Water quality monitoring included field measurements and collection of depth-discrete water samples for laboratory analysis.

The District has monitored bacteria levels present at swimming beaches at the Gavins Point Project since 2002. Five swimming beaches on Lewis and Clark Lake and one on Lake Yankton were monitored. Weekly grab samples were collected from May through September and analyzed for fecal coliform and *E. coli* bacteria.

Intensive water-quality surveys have recently been completed or are ongoing at all the Mainstem System projects. A 3-year intensive water-quality survey was completed at the Garrison Project in 2005, the Fort Peck Project in 2006, the Oahe Project in 2007, the Fort Randall Project in 2008, and the Big Bend and Gavins Point Projects in 2010. A 3-year intensive water-quality survey was initiated in 2010 on the Missouri River downstream of Gavins Point Dam. The monitoring objectives of the intensive surveys are to collect water quality data to spatially describe water quality conditions, and to collect information to facilitate the application of the CE-QUAL-W2 hydrodynamic and water quality model.

Water Quality Monitoring at the Mainstem System Powerplants

As part of the operation of the Mainstem System powerplants, water is drawn from the intake structure of each dam and piped through the powerplant in a "raw water" supply line that is tapped for various uses. The "raw water" supply line is an open ended, flow-through system (i.e., water is continually discharged). A monitoring station, that measures water quality conditions of water drawn from near the start of the "raw water" supply line, has been irregularly maintained at each of the powerplants over the past several years. Recent water quality monitoring has consisted of year-round, hourly measurements of temperature, dissolved oxygen, and conductivity through the use of a data-logger. Monthly grab samples (year-round) have also been collected and analyzed. The water quality conditions measured in the "raw water" supply lines of the powerplants are believed to represent the water quality conditions present in the reservoirs near the dam intakes and in the tailwaters (i.e., Missouri River) immediately downstream of the dam.

Water Quality Monitoring of the Lower Missouri

Since 2003, the District has cooperated with the Nebraska Department of Environmental Quality to monitor ambient water quality conditions along the Missouri River from Fort Randall Dam to Rulo, NE. Fixed-station monitoring has occurred at the following ten sites: Fort Randall Dam tailwaters; near Verdel, NE; near Niobrara, NE, Gavins Point Dam tailwaters; near Maskell, NE; near Ponca, NE; at Decatur, NE; at Omaha, NE; at Nebraska City, NE; and at Rulo, NE. Water quality monitoring consisted of taking field measurements and collecting near-surface grab samples monthly year-round. The collected grab samples were analyzed for various parameters.

A 3-year water-quality intensive survey of the Missouri River from Gavins Point Dam downstream to St. Louis Missouri was jointly implemented with the Kansas City District in 2010. In the Omaha District this included the addition of depth-profile measurements and depth-discrete sampling at the fixed station monitoring sites on the Missouri River at Gavins Point Dam tailwaters; near Ponca, NE;

at Decatur, NE; at Omaha, NE; at Nebraska City, NE; and at Rulo, NE. The intensive survey also includes water quality monitoring of several major tributaries just upstream of their confluence with the Missouri River. The monitored tributaries in the Omaha District include: James River (SD), Vermillion River (SD), Floyd River (IA), Little Sioux River (IA), Soldier River (IA), Boyer River (IA), Platte River (NE), Nishnabotna River (IA), Tarkio River (Mo), and Big Nemaha River (NE).

Water Quality Monitoring at the Mainstem System Ancillary Lakes

Lake Yankton, Lake Pocasse, and Lake Audubon are ancillary lakes to the Mainstem System reservoirs respectively at the Gavins Point, Oahe, and Garrison Projects. Water quality monitoring at these three lakes has been irregular in the past. The District initiated ambient water quality monitoring at the lakes in 2006 as part of a 3-year rotational monitoring cycle. These lakes were monitored in 2009. Monitoring included monthly sampling (May through September) at a near-dam deepwater location and included field measurements for depth profiling and water transparency and collection of near-surface and near-bottom water samples for laboratory analysis.

Water Quality Assessment Methods

For the purposes of this report, existing water quality is defined as water quality conditions that occurred during the past 5 years (i.e., 2006 through 2010). Water quality monitoring conducted during that period was used to describe existing water quality conditions.

Statistical analyses were performed on the water quality monitoring data collected at the Mainstem System reservoirs (including inflow and outflow sites), powerplants, on the Missouri River, and at the mainstem ancillary lakes. Descriptive statistics were calculated to describe central tendencies and the range of observations in existing water quality conditions. Monitoring results were compared to applicable water quality standards criteria established by the appropriate States pursuant to the Federal Clean Water Act.

Longitudinal contour plots were constructed when adequate depth-profile measurements were collected along the length of a reservoir. Adequate information was collected in 2010 to construct longitudinal contour plots at all of the Mainstem System reservoirs. At these reservoirs longitudinal contour plots were constructed for water temperature, dissolved oxygen, and turbidity.

Longitudinal box plots were constructed when adequate measurements were collected along the length of a waterbody. Adequate information was collected to construct longitudinal box plots of existing water quality conditions at all the Mainstem System reservoirs and the lower Missouri River.

Depending on their bathymetry, lakes can experience thermally-induced density stratification in the summer. This can lead to significant vertical water quality variation if hypoxic conditions develop in the hypolimnion. Measured water temperature and dissolved oxygen depth profiles were plotted at the Mainstem System reservoirs and mainstem ancillary lakes. The plotted depth profiles were measured at a near-dam, deepwater ambient monitoring location. Depth profiles measured in the summer months over the past 5 years were plotted. The plots were reviewed to assess the occurrence of thermal stratification and hypolimnetic dissolved oxygen degradation.

The variation of selected parameters with depth was evaluated, where possible, by comparing paired near-surface and near-bottom samples collected at the Mainstem System reservoirs and ancillary lakes. The paired samples were collected at the near-dam, deepwater monitoring location over the past 5 years. The parameters compared included water temperature, dissolved oxygen, ORP, pH, alkalinity, and various nutrients.

Annual seasonal time series plots of water temperatures measured in the Missouri River immediately upstream and downstream of the Mainstem System reservoirs were constructed to display temporal variation. Time series plots were also prepared for water quality conditions monitored at the Mainstem System powerplants during 2006 through 2010. Hourly water temperature, dissolved oxygen, and dam discharge were plotted semi-annually for the 5 years.

A lake Trophic State Index (TSI) was calculated from Secchi depth transparency, total phosphorus, and chlorophyll *a* measurements. Values for these three parameters were converted to an index number ranging from 0 to 100. This index value was used to determine the lake's trophic status in accordance with Table 4-1.

The phytoplankton and zooplankton communities at the Mainstem System reservoirs were assessed based on collected grab samples. Laboratory analyses consisted of identification of plankton taxa to the lowest practical level and quantification of phytoplankton taxa biovolume and zooplankton taxa biomass. These results were used to determine the relative abundance of plankton taxa at the division level based on the measured biovolume or biomass.

The impairment of beneficial uses designated in State water quality standards was evaluated by applying the impairment assessment criteria defined by the appropriate States for preparing their Integrated Water Quality Reports.

Surface water quality trends at the Mainstem System reservoirs were assessed by evaluating water clarity (i.e. Secchi depth), total phosphorus, chlorophyll *a*, and trophic state index (TSI) values from monitoring results obtained at long-term, fixed-station ambient monitoring sites for the 31-year period 1980 through 2010.

Water Quality Conditions Monitored at the Mainstem System Projects

Fort Peck

Monitoring of the existing water quality conditions at Fort Peck Reservoir (Fort Peck Lake) indicated no significant water quality concerns. On a few occasions measured dissolved oxygen concentrations were below the water quality standards criterion of 5 mg/l. The measured low dissolved oxygen concentrations occurred in the hypolimnion near the reservoir bottom during the later part of the summer thermal stratification period. Water temperature, dissolved oxygen, and turbidity in Fort Peck Lake vary temporally, longitudinally (from the dam to the reservoir's upper reaches), and vertically (from the reservoir's surface to the bottom). During the summer, a thermocline typically becomes established in the reservoir at a depth of about 20 meters. Parameters that varied significantly from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, dissolved oxygen, ORP, pH, and alkalinity. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). The dominant zooplankters' sampled in the reservoir were Cladocerans and Copepods. Over the past 31 years, Fort Peck Lake exhibited decreasing transparency and increasing chlorophyll *a* and TSI. During the 31-year period the lacustrine zone of Fort Peck Lake has generally remained in a mesotrophic state.

Water quality monitoring of the existing conditions of the Fort Peck Dam discharge did not indicate any water quality standards attainment concerns. There appeared to be little correlation between dam discharge rates and measured water temperature and dissolved oxygen. Inflow temperatures of the Missouri River to Fort Peck Lake are generally warmer than the outflow temperatures of Fort Peck Dam during March through August and cooler than the outflow temperatures during September through February. A maximum temperature difference occurs in the summer when the Missouri River inflow

temperature is about 10° to 12°C warmer than the Fort Peck Dam outflow temperature. Colder water temperatures and lower turbidity levels, attributed to the regulation of Fort Peck Dam, are believed to be impacting the endangered pallid sturgeon population in the Missouri River downstream of the dam.

Garrison

Monitoring of the existing water quality conditions of Garrison Reservoir (Lake Sakakawea) indicated possible water quality concerns regarding water temperature and dissolved oxygen for the support of coldwater fishery habitat during the drought-attributed low pool levels. Water temperatures in the epilimnion of the reservoir regularly exceed 15°C in the summer, while temperatures in the hypolimnion are less than 15°C. Dissolved oxygen levels in the hypolimnion continually degrade along the reservoir bottom as summer progresses, and can fall below 5.0 mg/l in late summer. Low dissolved oxygen conditions occur in the upstream reaches of the hypolimnion first and progress towards the dam. As the summer progresses, low dissolved oxygen conditions move up from the reservoir bottom into the mid- and upper reaches of the hypolimnion and pinch off coldwater habitat.. This pinching off of coldwater habitat threatens the occurrence of coldwater fishery habitat in Lake Sakakawea, especially under low pool levels during drought conditions.

Water temperature, dissolved oxygen, and turbidity in Lake Sakakawea vary temporally, longitudinally (from the dam to the reservoir's upstream reaches), and vertically (from the reservoir's surface to the bottom). During the summer, a thermocline typically becomes established in the reservoir at a depth of about 25 meters. Parameters that significantly varied from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, dissolved oxygen, ORP, and pH. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). The dominant zooplankters' sampled in the reservoir were Cladocerans and Copepods. Over the past 31 years, Lake Sakakawea exhibited no significant trends in transparency, total phosphorus, and chlorophyll *a* levels. Monitoring indicated that the lacustrine zone of Lake Sakakawea is currently in a mesotrophic state and shows no observable trend of an increasing trophic state over the past 31 years.

Water quality monitoring of the existing conditions of the Garrison Dam discharge did not indicate any significant water quality concerns. There is a significant correlation between dam discharge rates and measured water temperature and dissolved oxygen concentrations during the summer thermal stratification period of Lake Sakakawea. This indicates that the vertical extent of the withdrawal zone in the reservoir is dependent upon the discharge rate of the dam. This is believed to be a result of the design of the intake structure (i.e., bottom withdrawal) and the presence of the submerged intake channel leading to the intake structure. Water is likely drawn from an extended vertical zone in Lake Sakakawea year-round, but is only evident in the temperatures monitored at the powerhouse during reservoir thermal stratification during the summer. Inflow temperatures of the Missouri River to Lake Sakakawea are generally warmer than the outflow temperatures of Garrison Dam during April through September and cooler than the outflow temperatures during October through March. A maximum temperature difference occurs in the summer when the Missouri River inflow temperature is about 10°C warmer than the Garrison Dam outflow temperature.

As drought conditions persisted in early 2005, water levels in Lake Sakakawea had fallen to a record low pool elevation of 1805.8 ft-NGVD29 on May 12, 2005. At that time it was felt that, unless emergency water quality management measures were implemented in 2005 to preserve the coldwater habitat in the reservoir, the recreational sport fishery would likely be adversely impacted. The reduction of coldwater habitat is exacerbated by withdrawals through the Garrison Dam intake structure. Because the invert elevation of the intake portals to the Garrison Dam power tunnels (i.e., penstocks) is 2 feet above the reservoir bottom, water drawn through the penstocks comes largely from the lower depths of

the reservoir. Thus, during the summer thermal-stratification period, water is largely drawn from the hypolimnetic volume of Lake Sakakawea. Three short-term water quality management measures were identified for implementation in 2005 in an effort to preserve the coldwater habitat in the reservoir. These measures, which were implemented at Garrison Dam, included: 1) application of a plywood barrier to the dam's intake trash racks, 2) utilization of head gates to restrict the opening to the dam's power tunnels, and 3) modification of the daily flow cycle and minimum flow releases from the dam. The three implemented water quality management measures were targeted at drawing water into the dam from higher elevations within Lake Sakakawea. It is estimated the implementation of these short-term water quality management measures resulted in a potential saving of coldwater habitat in Lake Sakakawea of about 379,390 acre-ft in 2005; 1,021,150 acre-ft in 2006; 827,928 acre-ft in 2007; 794,850 acre-ft in 2008; and 87,060 acre-ft in 2009. The smaller potential saving of coldwater habitat in 2009 is attributed to the return of "normal" pool levels in 2009. With the return to "normal" pool levels, the plywood barriers were removed from Garrison Dam in October 2009.

Oahe

Monitoring of the existing water quality conditions of Oahe Reservoir (Lake Oahe) indicated possible water quality concerns regarding water temperature and dissolved oxygen for the support of Coldwater Permanent Fish Life Propagation. Water temperatures in the epilimnion of the reservoir regularly exceed the criterion of 18.3°C in the summer, while temperatures in the hypolimnion are less than 18.3°C. Dissolved oxygen levels in the hypolimnion continually degrade along the reservoir bottom as summer progresses and fall below the spawning criterion of 7 mg/l in late summer. Dissolved oxygen levels did not fall below the non-spawning criterion of 6 mg/l in the hypolimnion in the area of the reservoir near Oahe Dam. Dissolved oxygen concentrations regularly fall below 6 mg/l in the middle and upstream reaches of the hypolimnion. As the summer progresses, conditions of lower dissolved oxygen move up from the reservoir bottom into the lower reaches of the hypolimnion.

Water temperature, dissolved oxygen, and turbidity in Lake Oahe vary temporally, longitudinally (from the dam to the reservoir's upstream reaches), and vertically (from the reservoir's surface to the bottom). During the summer, a thermocline typically becomes established in the reservoir at a depth of about 20 meters. Parameters that significantly varied from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, ORP, pH, and alkalinity. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). The dominant zooplankters' sampled in the reservoir were Cladocerans and Copepods. Over the past 31 years, Lake Oahe exhibited no significant trends in transparency, total phosphorus, or chlorophyll *a* levels. Monitoring indicated that the lacustrine zone of Lake Oahe is currently in a mesotrophic state; however, recent monitoring indicates a significant trend of a degrading TSI.

Water quality monitoring of the existing conditions of the Oahe Dam discharge indicated possible water quality concerns regarding temperature for the support of Coldwater Permanent Fish Life Propagation. Temperatures of the water passed through Oahe Dam in the summer regularly exceeded the temperature criterion of 18.3°C. During the summer when Lake Oahe is thermally stratified, water temperatures in the epilimnion of the reservoir exceed 18.3°C, while temperatures in the hypolimnion are less than 18.3°C. Water discharged through Oahe Dam for power production is withdrawn from Lake Oahe at elevation 1525 ft-NGVD29, approximately 110 feet above the reservoir bottom. Thus, water withdrawn from the reservoir in the summer comes largely from the epilimnion, especially when pool elevations are lower due to drought conditions. Because water passed through Oahe Dam during the summer is withdrawn from the epilimnion of the reservoir, the temperature criterion of 18.3°C for the Missouri River and Big Bend Reservoir just downstream of the dam are not being met during the summer when Lake Oahe is thermally stratified.

There appeared to be little correlation between Oahe Dam discharge rates and measured water temperature and dissolved oxygen concentrations. Inflow temperatures of the Missouri River to Lake Oahe are generally warmer than the outflow temperatures of the Oahe Dam discharge during the period of April through June. Outflow temperatures of the Oahe Dam discharge are generally warmer than the inflow temperatures of the Missouri River during the period of July through March. A maximum temperature difference occurs in the fall when the Oahe Dam discharge temperature is about 4° to 6°C warmer than the Missouri River inflow temperature.

Big Bend

Water quality monitoring of the existing conditions of Big Bend Reservoir (Lake Sharpe) indicated possible water quality concerns regarding water temperature and dissolved oxygen for the support of Coldwater Permanent Fish Life Propagation (CPFLP). Due to its shallowness, a hypolimnion rarely forms in Lake Sharpe and water temperatures throughout the reservoir regularly exceed 18.3°C in the summer. Dissolved oxygen levels near the bottom of the reservoir occasionally fall below the 6 mg/l CPFLP criterion during the summer. Ambient summer water temperatures in Lake Sharpe do not appear to be cold enough to support CPFLP as defined by State water quality criteria. Consideration should be given to reclassify the reservoir for a warmwater permanent fish life propagation use based on a use attainability assessment of "natural conditions" regarding ambient water temperatures.

Lake Sharpe exhibits limited summer thermal stratification due to its shallower depth and the high discharge rates that occur through Big Bend Dam; however, temperature and dissolved oxygen can vary significantly during periods of stratification. Significant longitudinal variation in turbidity levels occurs on Lake Sharpe, especially following periods of significant inflows from the Bad River. Parameters that significantly varied from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, dissolved oxygen, ORP, pH, TKN, and total ammonia. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). The dominant zooplankters' sampled in the reservoir were Cladocerans and Copepods. Over the past 31 years, Lake Sharpe exhibited a significant trend for transparency (decreasing) and no significant trends for total phosphorus and chlorophyll *a*. Monitoring indicated that the lacustrine zone of Lake Sharpe is currently in a mesotrophic to moderately eutrophic state and shows a significant trend of increasing TSI over the past 30 years.

Monitoring of the existing water quality conditions of the Big Bend Dam discharge did not indicate any water quality concerns. There appeared to be only minor correlation between dam discharge rates and measured water temperature and dissolved oxygen concentrations. Inflow temperatures of the Missouri River to Big Bend Reservoir are about 4°C warmer than the outflow temperatures of Big Bend Dam during the winter. Temperatures of the Big Bend Dam discharge are about 5°C warmer than the inflow temperatures of the Missouri River during the spring, summer, and fall.

Fort Randall

Monitoring of the existing water quality conditions of Fort Randall Reservoir (Lake Francis Case) indicated possible water quality concerns regarding dissolved oxygen and suspended solids for the support of Warmwater Permanent Fish Life Propagation. Dissolved oxygen levels in the hypolimnion degrade along the reservoir bottom as summer progresses and fall below 5 mg/l in July and August. With the near-bottom withdrawal at Fort Randall Dam, low dissolved levels (less than 5 mg/l) also occur in the tailwaters immediately downstream of Fort Randall Dam. The chronic suspended solids water quality standards criterion was exceeded in Lake Francis Case in the area near the confluence of the White River.

Water temperature, dissolved oxygen, and turbidity in Lake Francis Case vary temporally, longitudinally (from the dam to the reservoir's upstream reaches), and vertically (from the reservoir's surface to the bottom). During the summer, a thermocline typically becomes established in the reservoir at a depth of about 25 meters. Parameters that significantly varied from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, dissolved oxygen, ORP, and pH. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). The dominant zooplankters' sampled in the reservoir were Cladocerans and Copepods. Over the past 31 years, Lake Francis Case exhibited a significant trend in transparency (decreasing), and no significant trends in total phosphorus and chlorophyll *a*. Monitoring indicated that the near-dam lacustrine zone of Lake Francis Case is currently in a mesotrophic state but shows an increasing trend in TSI over the past 31 years.

Water quality monitoring of the existing conditions of the Fort Randall Dam discharge and tailwaters indicate a possible dissolved oxygen concern. Thermal stratification of Lake Francis Case during the summer results in the development of hypoxic conditions in the reservoir's hypolimnion. Lake Francis Case is a bottom-release reservoir, and hypoxic water is passed through Fort Randall Dam during power production in July and August. Under these conditions, dissolved oxygen levels in areas of the Fort Randall Dam tailwaters fall below South Dakota's water quality standards' minimum dissolved oxygen criterion of 5 mg/l. Monitored conditions indicate that the low dissolved oxygen levels in the tailwaters are not seemingly impairing the designated Warmwater Permanent Fish Life Propagation beneficial use as regions of refugia exist in the impacted area. Also, there is no evidence of past fish kills in the Fort Randall tailwaters attributable to hypoxic conditions. If warranted, dissolved oxygen conditions in the Fort Randall tailwaters during periods of hypoxic dam releases could be mitigated by spilling water from the reservoir surface down the spillway.

There is a significant correlation between dam discharge rates and measured water temperature and dissolved oxygen concentrations during the summer thermal stratification period of Lake Francis Case. This indicates that the vertical extent of the withdrawal zone in the reservoir is dependent upon the discharge rate of the dam. This is believed to be a result of the design of the intake structure (i.e., bottom withdrawal) and the presence of the submerged approach channel leading to the intake structure. Water is likely drawn from an extended vertical zone in Lake Francis Case year-round, but is only evident in the temperature and dissolved oxygen levels monitored at the powerhouse when the reservoir is thermally stratified during the summer.

Inflow temperatures of the Missouri River to Fort Randall tend to be at little warmer than the outflow temperatures of Fort Randall Dam during the spring and early summer. Outflow temperatures of the Fort Randall Dam discharge tend to be a little warmer than the Missouri River inflow temperatures in the late-summer and fall.

Gavins Point

Water quality monitoring of the existing conditions of Gavins Point Reservoir (Lewis and Clark Lake) indicated a possible water quality concern regarding nutrients. The Nebraska "nutrient criteria" for total phosphorus and chlorophyll *a* applicable to Lewis and Clark Lake were regularly exceeded throughout the reservoir, and exceed impairment criteria identified by the State of Nebraska for the protection of aquatic life. It is also noted that the estimated loss of 24.3 percent of the"as-built" multi-purpose pool volume of Lewis and Clark Lake is approaching Nebraska's impairment identification criterion of 25 percent volume loss.

Water temperature, dissolved oxygen, and turbidity in Lewis and Clark Lake vary temporally, longitudinally (from the dam to the reservoir's upstream reaches), and vertically (from the reservoir's

surface to the bottom). During periods of calm weather in the summer, Lewis and Clark Lake develops a slight thermal stratification. When this slight stratification occurs, a thermocline is present at about 8 meters depth. This indicates the reservoir is probably polymixic. The thermal stratification breaks down under windier conditions, given the shallow depth of the reservoir, and the reservoir mixes throughout its water column. Parameters that significantly varied from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, dissolved oxygen, ORP, pH, alkalinity, total organic carbon, total ammonia, and total phosphorus. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). The dominant zooplankters' sampled in the reservoir were Cladocerans and Copepods. Over the past 31 years, Lewis and Clark Lake exhibited a significant trend for transparency (decreasing) and no significant trends in total phosphorus and chlorophyll *a* levels. Monitoring indicated that the lacustrine zone of Lewis and Clark Lake is currently in a eutrophic state and shows an increasing trend in TSI.

Water quality monitoring of the existing conditions of the Gavins Point Dam discharge did not indicate any water quality concerns. There appeared to be little correlation between dam discharge rates and measured water temperature and dissolved oxygen concentrations. Inflow temperatures of the Missouri River to Lewis and Clark Lake tend to be at little cooler than the outflow temperatures of Gavins Point Dam during the spring and early summer. Outflow temperatures of the Gavins Point Dam discharge tend to be a little cooler than the Missouri River inflow temperatures in the late-summer and fall.

Comparison of Water Quality Conditions at the Mainstem Reservoirs

A comparison of existing water quality conditions monitored at the Mainstem System reservoirs is provided in Table 5-29 and Table 5-30.

Lower Missouri River

Monitoring of the existing water quality conditions of the lower Missouri River from Gavins Point Dam to Rulo, Nebraska indicated no major water quality concerns. Longitudinal variation in selected water quality parameters was assessed with box plots arranged relative to their respective locations along the Missouri River. Parameters that exhibited no observable longitudinal trend included pH, specific conductance, total organic carbon, and total ammonia. Parameters that slightly decreased in a downstream direction included dissolved oxygen. Parameters that slightly increased in a downstream direction included chemical oxygen demand, total Kjeldahl nitrogen, and atrazine. Parameters that greatly increased in downstream direction included chloride, turbidity, total suspended solids, nitrate-nitrite nitrogen, and total phosphorus.

Existing Nutrient Concentrations and Loadings along the Missouri River from Montana to Nebraska

A box plot of nitrate-nitrite nitrogen, total nitrogen, and total phosphorus concentrations monitored along the Missouri River from near Landusky, Montana to Rulo, Nebraska over the 5-year period 2006 through 2010 is provided in Figure 6-3. A bar chart of estimated mean daily loads of the same nutrients based on calculated flux rates over the 5-year period is provided in Figure 6-4.

Mainstem Ancillary Lakes

Monitoring of existing water quality conditions at Lakes Audubon and Yankton indicated no major water quality concerns. Monitoring at Lake Pocasse indicated that the lake is in a hypereutrophic state.

Water Quality Monitoring and Management Activities Planned for Future Years

A tentative schedule of water quality monitoring targeted for implementation over the next 5 years at the Mainstem System Projects is given in Table 8-1. The identified data collection activities are considered the minimum needed to allow for the annual assessment of water quality conditions at District projects, and the preparation of water quality reports and water quality management objectives for the Mainstem System Projects. The actual monitoring activities that are implemented will be dependent upon the availability of future resources.

The CE-QUAL-W2 hydrodynamic and water quality model is being applied to facilitate the development water quality reports and project-specific water quality management objectives. The tentative schedule for implementing these water-quality management planning activities at the Mainstem System Projects is given in Table 8-2.

1 INTRODUCTION

1.1 OMAHA DISTRICT WATER QUALITY MANAGEMENT PROGRAM

The Omaha District (District) of the U.S. Army Corps of Engineers (Corps) is implementing a Water Quality Management Program (WQMP) as part of the operation and maintenance activities associated with managing the Corps' civil works projects in the District. The WQMP addresses surface water quality management issues and adheres to the guidance and requirements specified in the Corps' Engineering Regulation – ER 1110-2-8154, "Water Quality and Environmental Management for Corps Civil Works Projects" (USACE, 1995). To guide implementation of the WQMP, the District maintains a Program Management Plan (PgMP) that is annually reviewed. The current PgMP identifies the following four goals for the District's WQMP (USACE, 2011a):

1) Ensure that surface water quality, as affected by District projects and their regulation, is suitable for Project purposes, existing water uses, public health and safety, and is in compliance with applicable Federal, Tribal, and State water quality standards.
2) Establish and maintain a surface water quality monitoring and data evaluation program that facilitates the achievement of surface water quality management objectives, allows for the characterization of surface water quality conditions, and defines the influence of District Projects on surface water quality.
3) Establish and maintain strong working partnerships and collaboration with appropriate entities within and outside the Corps regarding surface water quality management at District Projects.
4) Document the water quality management activities of the District's Water Quality Management Program and surface water quality conditions at District Projects to record trends, identify problems and accomplishments, and provide guidance to program and Project managers.

The reporting of water quality conditions is done to document and assess water quality conditions occurring at Corps civil works projects in the District. This report describes existing and historic water quality conditions and identifies any evident surface water quality management issues. The reporting of water quality conditions is done to facilitate water quality management decisions regarding the operation and regulation of Corps projects.

1.2 CORPS MISSOURI RIVER MAINSTEM SYSTEM PROJECTS WITHIN THE OMAHA DISTRICT

The location of the Corps' Missouri River Mainstem System (Mainstem System) civil works project areas within the District and background information on the projects are provided in Figure 1-1 and Table 1-1. These are the Mainstem System civil works projects under the purview of the District's WQMP.

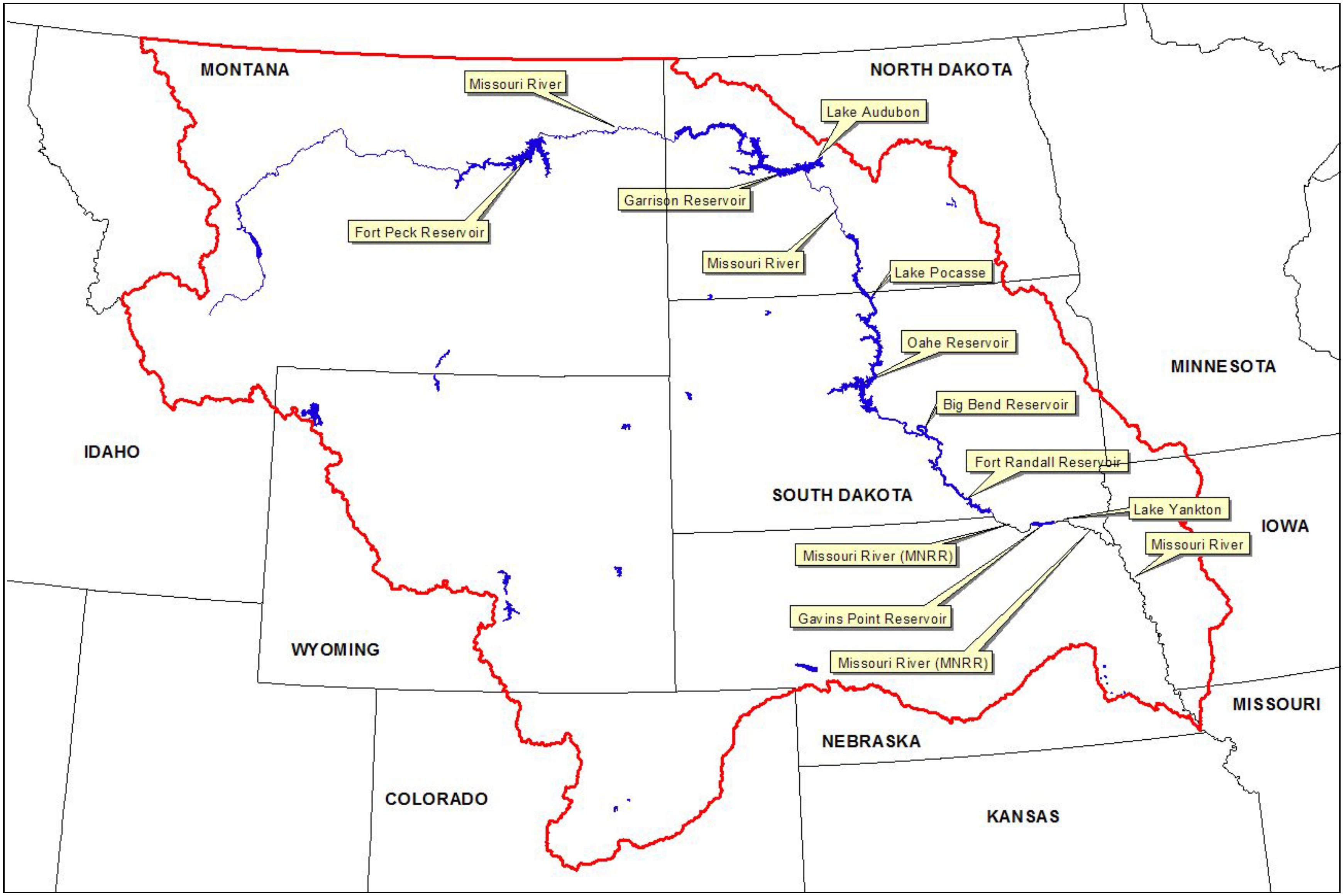


Figure 1-1. Missouri River Mainstem System civil works projects in the Omaha District. (Refer to Table 1-1 for project information.)

Table 1-1. Background information for Corps Missouri River Mainstem System project areas located in the Omaha District**.**

Project Area	Location	Dam Closure	Lake Size or River Length[(1)]	Authorized Proposes[(2)]	Water Quality Designated Beneficial Uses[(3)]
MAINSTEM RESERVOIRS					
Fort Peck (Fort Peck Lake)	Fort Peck, MT	1937	246,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig[(4)]	Rec, FW, WAL, DWS, IWS, AWS
Garrison (Lake Sakakawea)	Garrison, ND	1953	380,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig[(5)]	Rec, FW, CAL, DWS, IWS, AWS
Oahe (Lake Oahe)	Pierre, SD	1958	374,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig[(4)]	Rec, FW, CAL, DWS, IWS, AWS
Big Bend (Lake Sharpe)	Chamberlain, SD	1963	61,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig[(4)]	Rec, FW, CAL, DWS, IWS, AWS
Fort Randall (Lake Francis Case)	Pickstown, SD	1952	102,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig[(4)]	Rec, FW, WAL, DWS, IWS, AWS
Gavins Point (Lewis and Clark Lake)	Yankton, SD	1955	31,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig[(4)]	Rec, FW, WAL, DWS, IWS, AWS, Aes
MAINSTEM RESERVOIR ANCILLARY LAKES					
Lake Audubon (Garrison Project – Snake Creek Dam)	Garrison, ND	1952	18,780 A (mp)	Rec, FW	Rec, FW, WAL, DWS, IWS, AWS
Lake Pocasse (Oahe Project – Spring Creek Dam)	Pollock, SD	1961	1,545 A (mp)	FW	Rec, FW, WAL, AWS
Lake Yankton (Gavins Point Project)	Yankton, SD	1955	250 A	Rec, FW	Rec, WAL, AWS, Aes
MISSOURI RIVER					
Fort Peck Reach	Fort Peck Dam to Lake Sakakawea	-----	204 M	-----	Rec, FW, CAL, WAL, DWS, IWS, AWS
Garrison Reach	Garrison Dam to Lake Oahe	-----	87 M	-----	Rec, FW, WAL, DWS, IWS, AWS
Oahe Reach	Oahe Dam to Lake Sharpe	-----	5 M	-----	Rec, FW, CAL, DWS, IWS, AWS
Fort Randall Reach	Fort Randall Dam to Lewis and Clark Lake	-----	39 M	National Recreational River[(6)]	Rec, FW, WAL, DWS, IWS, AWS, Aes, OSRW
Gavins Point Reach	Gavins Point Dam to Ponca, NE	-----	59 M	National Recreational River[(6)]	Rec, FW, WAL, DWS, IWS, AWS, Aes, OSRW
Kensler's Bend Reach	Ponca, NE to Sioux City, IA	-----	17 M	-----	Rec, FW, WAL, DWS, IWS, AWS, Aes, OSRW
Lower Missouri River Reach	Sioux City, IA to Rulo, NE	-----	237 M	BS, Nav	Rec, FW, WAL, DWS, IWS, AWS, Aes

(1) A = acres, M = miles, mp = top of multipurpose pool, cp = top of conservation pool.

(2) Purposes authorized under Federal laws for the operation of the Corps projects.

FC = Flood Control, Rec = Recreation, FW = Fish & Wildlife, HP = Hydroelectric Power, WS = Water Supply, WQ = Water Quality, Nav = Navigation, Irrig = Irrigation, BS = Bank Stabilization.

(3) Water quality dependent beneficial uses designated to the waterbody in State water quality standards pursuant to the Federal Clean Water Act.

Rec = Recreation, FW = Fish and Wildlife, WAL, Warmwater Aquatic Life, CAL = Coldwater Aquatic Life, DWS = Domestic Water Supply, IWS = Industrial Water Supply, AWS = Agricultural Water Supply, Aes = Aesthetics, OSRW = Outstanding State Resource Water.

(4) Section 8 (PL 78-534) Federal irrigation has not been developed at this project; however, water is being withdrawn for private irrigation use.

(5) There is a Section 8 Federal irrigation project authorized at this project, but it is not yet operational; however, water is being withdrawn for private irrigation use.

(6) Designated a Recreational River under the Federal Wild and Scenic Rivers Act.

1.3 WATER QUALITY MONITORING GOALS AND OBJECTIVES

The District has established purposes and monitoring objectives for surface water quality monitoring under the WQMP. These monitoring purposes and objectives were established to meet the water quality information needs of the WQMP and the water quality management objectives, data collection rules and objectives, data application guidance, and reporting requirements identified in ER 1110-2-8154. The following purposes and monitoring objectives have been identified:

Purpose 1: Determine surface water quality conditions at District Projects.

Monitoring Objectives:

- For new District water resource projects, establish baseline surface water quality conditions as soon as possible and appropriate.
- Characterize the spatial and temporal distribution of surface water quality conditions at District Projects.
- Identify pollutants and their sources that are impacting surface water quality and the aquatic environment at District Projects.
- Evaluate water/sediment interactions and their impact on overall surface water quality at District Projects.
- Identify the presence and concentrations of contaminants in indicator and human-consumed fish species at District Projects.
- Investigate unique events (e.g., fish kills, hazardous waste spills, operational emergencies, health emergencies, public complaints, etc.) at District Projects that may have degraded surface water quality or impacted the aquatic environment.

Purpose 2: Document surface water quality concerns that are due to the operation and reservoir regulation of District Projects.

Monitoring Objectives:

- Determine if surface water quality conditions at District Projects or attributable to District operations or reservoir regulation (i.e., downstream conditions resulting from reservoir discharges) meets applicable Federal, Tribal, and State water quality standards.
- Determine if surface water quality conditions at District Projects or attributable to District operations or reservoir regulation are improving, degrading, or staying the same over time.
- Apply water quality models to assess surface water quality conditions at District Projects.

Purpose 3: Provide data to support Project operations and reservoir regulation for effective management and enhancement of surface water quality and the aquatic environment.

Monitoring Objectives:

- Provide surface water quality data required for real-time regulation of District Projects.
- Collect the information needed to design, engineer, and implement measures or modifications at District Projects to enhance surface water quality and the aquatic environment.

Purpose 4: Evaluate the effectiveness of structural or regulation measures implemented at District Projects to enhance surface water quality and the aquatic environment.

Monitoring Objectives:

- Evaluate the effectiveness of implemented measures at District Projects to improve surface water quality and the aquatic environment.

1.4 DATA COLLECTION APPROACHES

Several data collection approaches have been identified by the District for collecting surface water quality data. Pertinent surface water quality monitoring approaches are:

- Long-term, fixed-station ambient monitoring;
- Intensive surveys;
- Special studies; and
- Investigative monitoring.

Long-term, fixed-station ambient monitoring is intended to provide information that will allow the District to determine the status and trends of surface water quality conditions at District Projects. This type of sampling consists of systematically collecting samples at the same location over a long period of time (e.g., collecting monthly water samples at the same site for several years).

Intensive surveys are intended to provide more detailed information regarding surface water quality conditions at District Projects. They typically will include more sites sampled over a shorter timeframe than long-term fixed-station monitoring. Intensive surveys will provide the detailed information needed to thoroughly understand surface water quality conditions at a Project.

Special studies are conducted to address specific information needs. Special studies may be undertaken to collect the information needed to "scope-out" a specific surface water quality problem, apply water quality models, design and engineer modifications at Projects, or evaluate the effectiveness of implemented surface water quality management measures.

Investigative monitoring is typically initiated in response to an immediate need for surface water quality information at a District Project. This may be in response to an operational situation, the occurrence of a significant pollution event, public complaint, or a report of a fish kill. Any District response to a pollution event or fish kill would need to be coordinated with the appropriate Tribal, State, and Local authorities. The type of sampling that is done for investigative purposes is highly specific to the situation under investigation.

1.5 GENERAL WATER QUALITY CONCERNS IN THE OMAHA DISTRICT

1.5.1 RESERVOIR EUTROPHICATION AND HYPOLIMNETIC DISSOLVED OXYGEN DEPLETION

Reservoirs are commonly classified or grouped by trophic or nutrient status. The natural progression of reservoirs through time is from an oligotrophic (i.e., low nutrient/low productivity) through a mesotrophic (i.e., intermediate nutrient/intermediate productivity) to a eutrophic (i.e., high nutrient/high productivity) condition. The tendency toward the eutrophic or nutrient-rich status is common to all impounded waters. The eutrophication, or enrichment process, can be accelerated by nutrient additions to the reservoir resulting from cultural activities.

As deeper, temperate lakes warm in the spring and summer they typically become thermally stratified, due to the density differences of the water, into three vertical zones: 1) epilimnion, 2) metalimnion, and 3) hypolimnion. The epilimnion is the upper zone of less dense, warmer water in the lake that remains relatively mixed due to wind action and convection. The metalimnion is the middle zone that represents the transition from warm surface water to cooler bottom water. The hypolimnion is the bottom zone of more dense, colder water that is relatively quiescent.

A significant water quality concern that can occur in reservoirs that thermally stratify in the summer is the depletion of dissolved oxygen levels in the hypolimnion. The depletion of dissolved oxygen is attributed to the differing density of water with temperature, the utilization of dissolved oxygen in the decomposition of organic matter, and the oxidation of reduced inorganic substances. When density differences become significant, the deeper colder water is isolated from the surface and re-oxygenation from the atmosphere. In eutrophic lakes, the decomposition of the abundant organic matter can significantly reduce dissolved oxygen in the quiescent hypolimnetic zone. Hypoxic conditions in the hypolimnion can result in the release of sediment-bound substances (e.g., phosphorus, metals, sulfides, etc.) as the reduced conditions intensify and result in the production of toxic and caustic substances (e.g., hydrogen sulfide, etc.). Most fish and other intolerant aquatic life cannot inhabit water with less than 4 to 5 mg/l dissolved oxygen for extended periods. These conditions can impact aquatic life in the reservoir and also in waters downstream of the reservoir if its releases are from a bottom outlet.

1.5.2 SEDIMENTATION

Sedimentation is a process that reduces the usefulness of reservoirs. In the design and construction of reservoirs, the Corps will commonly allow for additional volume to accommodate sedimentation. The incoming sediment can seriously affect the reservoir ecology, fisheries, and benthic aquatic life. The reservoir can suffer ecological damage before a volume function such as flood control is impacted. The influx of sediment eliminates fish habitat, adds nutrients, destroys aesthetics, and decreases biodiversity. Working closely with the project sponsors in an effort to manage sediment input could ultimately prolong reservoir life. Wetlands or sediment traps could be constructed at the headwaters of a reservoir, either upstream of the reservoir or in a portion of the reservoir's upper end, to trap sediment.

1.5.3 SHORELINE EROSION

Shoreline erosion is a major problem occurring on nearly all reservoirs located in areas of erodible soils such as the Midwestern United States. Over 6,000 miles of reservoir shoreline exist at District Projects, and it is estimated that over 70 percent of this shoreline is eroding. Some locations have been protected, such as recreational and archaeological sites, but most of the shoreline continues to erode. Continued loss of the shoreline habitat (littoral zone) results in the loss of fishery habitat as well as loss of habitat for other biota such as aquatic vegetation and benthic invertebrates.

1.5.4 BIOACCUMULATION OF CONTAMINANTS IN AQUATIC ORGANISMS

Bioaccumulation is the accumulation of contaminants in the tissue of organisms through any route, including respiration, ingestion, or direct contact with contaminated water or sediment. Bioavailable, for chemicals, is the state of being potentially available for biological uptake by an aquatic organism when that organism is processing or encountering a given environmental medium (e.g., the chemicals that can be extracted by the gills from the water as it passes through the respiratory cavity or the chemicals that are absorbed by internal membranes as the organism moves through or ingests sediment). In the aquatic environment, a chemical can exist in three different basic forms that affect availability to organisms: 1) dissolved, 2) sorbed to biotic or abiotic components and suspended in the water column or deposited on the bottom, and 3) incorporated (accumulated) into organisms. Bioconcentration is a process by which there is a net accumulation of a chemical directly from water into aquatic organisms resulting from simultaneous uptake (e.g., by gill or epithelial tissue) and elimination. Biomagnification is the result of the process of bioconcentration and bioaccumulation by which tissue concentrations of bioaccumulated chemicals increase as the chemical passes up through two or more trophic levels. The term implies an efficient transfer of a chemical from food to consumer so that residual concentrations increase systematically from one trophic level to the next.

Bioaccumulation of contaminants can have a direct effect on aquatic organisms. These effects can be chronic (reduced growth, fecundity, etc.) and acute (lethality). The bioaccumulation of contaminants can also be a concern to human health when the contaminated tissue of aquatic organisms is consumed by humans.

1.5.5 OCCURRENCE OF PESTICIDES

Pesticides are widely applied to lands throughout the District. Pesticides detected at District Projects over the past 5 years include: acetochlor, alachlor, atrazine, chloropyrifos, deethylatrazine, deisopropylatrazine, dimethenamid, metolachlor, metribuzin, oxyfluorfen, profluralin, prometon, and propazine. Many of these pesticides do not have State or Federal numeric water quality criteria established.

1.5.6 URBANIZATION

Construction methods used to develop urban areas disturb the land and allow sediment-laden runoff to impact nearby streams and lakes. Best management practices (BMPs) to minimize construction-associated sedimentation damages are used ineffectively in many cases. BMPs to control the impact of construction practices include; sediment retention basins, phased "grading", and runoff control (e.g. hay bales, silt fences, vegetative ground cover, terracing, etc). Efforts need to be made to prevent sedimentation from off-project construction activities from causing impacts to District Projects. This could be accomplished by the appropriate State, County, or City agencies working with developers.

Post-construction problems may be associated with storm drainage and urban pollution. The conversion of grasslands or forests to roads, rooftops, sidewalks, and other water impervious surfaces make stream flows more variable and increase the frequency of high flow events. In addition, pollutants associated with urban drainage can impact downstream waterbodies. Storm sewer outlets can be allowed on Project lands provided detention in the form of ponds, swales, or wetlands exist on private property. A developer may be asked to construct a series of wetlands to slow downhill flows and provide time for bacterial die-off, chemical degradation, reduced flow rates, and sediment settling.

1.6 PRIORITIZATION OF DISTRICT-WIDE WATER QUALITY MANAGEMENT ISSUES

The District has identified eight priority issues for water quality management. These priority issues are listed in Table 1-2.

Table 1-2. Priority water quality management issues within the Omaha District.

	Missouri River Mainstem System Water Quality Management Issues
➢	Determine how regulation of the Missouri River Mainstem System (Mainstem System) dams affects water quality in the impounded reservoir and downstream river. Utilize the CE-QUAL-W2 hydrodynamic and water quality model to facilitate this effort.
➢	Evaluate how eutrophication is progressing in the Mainstem System reservoirs, especially regarding the expansion of anoxic conditions in the hypolimnion during summer stratification.
➢	Determine how flow regime, especially the release of water from Mainstem System projects, affects water quality in the Missouri River.
➢	Determine how current water quality conditions in the Missouri River (e.g., water temperature, turbidity, etc.) may be affecting pallid sturgeon populations in the Missouri River system.
	District-Wide Water Quality Management Issues
➢	Provide water quality information to support Corps reservoir regulation elements for effective surface water quality and aquatic habitat management.
➢	Provide water quality information and technical support to the Tribes and States in the development of their Section 303(d) lists and development and implementation of TMDLs at District Projects.
➢	Identify existing and potential surface water quality problems at District Projects and develop and implement appropriate solutions.
➢	Evaluate surface water quality conditions and trends at District Projects.

1.7 PROJECT-SPECIFIC WATER QUALITY MANAGEMENT ISSUES AT THE MAINSTEM SYSTEM PROJECTS

1.7.1 SECTION 303(D) LISTINGS OF IMPAIRED WATERS

Under Section 303(d) of the Federal Clean Water Act (CWA), Tribes and States, with the delegated authority from the U.S. Environmental Protection Agency (EPA), are required to prepare a periodic list of impaired waters [i.e., Section 303(d) list]. Impaired waters refer to those waterbodies where it has been determined that technology-based effluent limitations required by Section 301 of the CWA are not stringent enough to attain and maintain applicable water quality standards. Tribes and States, as appropriate, are required to establish and implement Total Maximum Daily Loads (TMDLs) for waterbodies on their Section 303(d) lists.

1.7.2 FISH CONSUMPTION ADVISORIES

Fish are capable of accumulating many toxic substances in excess of 1,000 times the concentrations found in surface waters. The public has expressed concerns on whether fish caught from District Project waters are safe to consume. It is important that answers to public health concerns be based on substantiated knowledge of toxicants in fish fillets and the public health risks associated with measured toxicant concentrations. This type of information can be used by States when considering the issuance of fish consumption advisories. Fish consumption advisories have been issued for fish caught from certain District Project waters. Mercury is the most prevalent contaminant leading to the issuance of fish consumption advisories in the District.

1.7.3 SUMMARY OF PROJECT-SPECIFIC TMDL CONSIDERATIONS, FISH CONSUMPTION ADVISORIES, AND OTHER WATER QUALITY MANAGEMENT ISSUES

Table 1-3 summarizes TMDL considerations, fish consumption advisories, and other surface water quality management issues applicable to the Mainstem System Projects. The identified impaired uses, pollutant/stressors, and fish tissue contamination identified in Table 1-3 are taken directly from the appropriate State 303(d) impaired waters listings and issued fish consumption advisories. They are provided for information purposes and are not based on water quality monitoring conducted by the District. The other surface water quality management issues listed in Table 1-3 were identified by District surface water quality monitoring and Corps surface water quality management concerns. Surface water quality management issues at specific Mainstem System Projects will be assessed in detail in surface water quality reports prepared for the Project by the District.

Table 1-3. Summary of site-specific water quality management issues and concerns for Missouri River Mainstem System projects areas in the Omaha District.

Project Area	TMDL Considerations*				Fish Consumption Advisories		Other Water Quality Management Issues
	On 303(d) List	Impaired Uses	Pollutant/Stressor	TMDL Completed	Advisory in Effect	Identified Contamination	
Missouri River (Bullwhacker Creek to Fort Peck Reservoir)	Yes	Aquatic Life Warmwater Fishery Drinking Water Supply	Degraded riparian vegetation Arsenic Copper	No	No	-----	Pallid sturgeon recovery priority area
Fort Peck Lake	Yes	Drinking Water Supply	Lead, Mercury	No	Yes	Mercury	-----
Missouri River (Fort Peck Dam to the Milk River)	Yes	Aquatic Life Coldwater Fishery	Degraded riparian vegetation Other flow regime alterations Water Temperature	No	No	-----	Pallid sturgeon recovery priority area
Missouri River (Milk River to the Poplar River)	Yes	Aquatic Life Warmwater Fishery	Degraded riparian vegetation Other flow regime alterations Water Temperature	No	No	-----	Pallid sturgeon recovery priority area
Missouri River (Poplar River to MT/ND State line)	Yes	Aquatic Life Warmwater Fishery	Water Temperature Other flow regime alterations	No	No	-----	Pallid sturgeon recovery priority area
Lake Sakakawea	Yes	Fish Consumption	Methyl-Mercury	No	Yes	Mercury	Hypolimnetic dissolved oxygen
Missouri River (Garrison Dam tailwaters)	No	-----	-----	-----	Yes	Mercury	Low dissolved oxygen in Garrison Dam tailwaters (associated with bottom reservoir withdrawals)
Lake Oahe (Cheyenne River Area)	No	----	-----	-----	Yes	Mercury	Issued by the Cheyenne River Sioux Tribe for Lake Oahe, Cheyenne River, and Moreau River within their tribal lands.
Lake Pocasse (Lake Oahe)	Yes	Immersion Recreation	*E. coli*	No	No	-----	-----
Lake Sharpe	Yes	Coldwater Fishery	Water Temperature Sediment**	No Yes**	No	-----	-----
Missouri River (Fort Randall Dam to Lewis and Clark Lake)	No	-----	-----	-----	No	-----	Low dissolved oxygen in Fort Randall Dam tailwaters (associated with bottom reservoir withdrawals) National recreational river Pallid sturgeon recovery priority area
Lewis and Clark Lake	Yes	Aquatic Life	Nutrients (Total Nitrogen and Total Phosphorus)	-----	No	-----	Sedimentation Emergent aquatic vegetation
Missouri River (Gavins Pt Dam to Rulo, NE)							Pallid sturgeon recovery priority area
• Gavins Pt Dam to Big Sioux River	No			-----	No		National recreational river
• Big Sioux River to Platte River	Yes	Aquatic Life	Cancer Risk and Hazard Index Compounds (Dieldrin and PCBs in fish tissue)	No	Yes	Dieldrin PCBs	Summer ambient water temperature (NPDES limitations regarding cooling water discharges)
• Council Bluffs, IA)	Yes	Drinking Water Supply	Arsenic	No	-----	-----	-----
• Platte River to Nebraska-Kansas Border	Yes	Recreation Aquatic Life	Cancer Risk and Hazard Index Compounds (Dieldrin and PCBs in fish tissue) *E. coli* Bacteria	Yes/No	Yes	Dieldrin PCBs	TMDL developed for *E. coli.* Summer ambient water temperature (NPDES limitations regarding cooling water discharges)

* Information taken from published State Total Maximum Daily Load (TMDL) 303(d) reports and listings as of January 1, 2011.

** TMDL developed for sediment. A nonpoint source management project is being implemented in the Bad River watershed.

2 LIMNOLOGICAL PROCESSES IN RESERVOIRS

Many of the Corps civil works projects in the District involve the operation and maintenance of a reservoir or the regulation of flows discharged from reservoirs. Much of the surface water quality monitoring conducted by the District is done to determine existing water quality conditions and identify water quality management concerns at these reservoirs. A basic understanding of the limnological processes that occur in reservoirs is needed to interpret the surface water quality information provided in this report. The following discussion provides a basic overview of limnological processes that occur in reservoirs.

2.1 VERTICAL AND LONGITUDINAL WATER QUALITY GRADIENTS

The annual temperature distribution represents one of the most important limnological processes occurring within a reservoir. Thermal variation in a reservoir results in temperature-induced density stratification, and an understanding of the thermal regime is essential to surface water quality assessment. Deep, temperate-zone lakes typically completely mix from the surface to the bottom twice a year (i.e., dimictic). Temperate-zone dimictic lakes exhibit thermally-induced density stratification in the summer and winter months that is separated by periods of "turnover" in the spring and fall. This stratification typically occurs through the interaction of wind and solar insolation at the lake surface and creates density gradients that can influence lake water quality. During the summer, solar insolation has its highest intensity and the reservoir becomes stratified into three zones: 1) epilimnion, 2) metalimnion, and 3) hypolimnion.

Epilimnion: The epilimnion is the upper zone that consists of the less dense, warmer water in the reservoir. It is fairly turbulent since its thickness is determined by the turbulent kinetic energy inputs (e.g., wind, convection, etc.), and a relatively uniform temperature distribution throughout this zone is maintained.

Metalimnion: The metalimnion is the middle zone that represents the transition from warm surface water to colder bottom water. There is a distinct temperature gradient through the metalimnion. The metalimnion contains the thermocline that is the plane or surface of maximum temperature rate change.

Hypolimnion: The hypolimnion is the bottom zone of more dense, colder water that is relatively quiescent. Bottom withdrawal or fluctuating water levels in reservoirs, however, may significantly increase hypolimnetic mixing.

Long, dendritic reservoirs with tributary inflows located a considerable distance from the outflow and unidirectional flow from headwater to dam develop gradients in space and time (USACE, 1987). Although these gradients are continuous from headwater to dam, three characteristic zones result: a riverine zone, a zone of transition, and a lacustrine zone (USACE, 1987).

Riverine Zone: The riverine zone is relatively narrow and well mixed, and there is a significant decrease in water current velocities. Advective forces are still sufficient to transport significant quantities of suspended particles, such as silts, clays, and organic particulate. Light penetration in this zone is minimal and may be the limiting factor that controls primary productivity in the water column. The decomposition of tributary organic loadings often creates a significant oxygen demand, but an aerobic environment is maintained because the riverine zone is generally shallow and well mixed. Longitudinal dispersion may be an important process in this zone.

Zone of Transition: Significant sedimentation occurs through the transition zone, with a subsequent increase in light penetration. Light penetration may increase gradually or abruptly, depending on the flow regime. At some point within the mixed layer of the zone of transition, a

compensation point between the production and decomposition of organic matter should be reached. Beyond this point, production of organic matter within the reservoir mixed layer should begin to dominate.

Lacustrine Zone: The lacustrine zone is characteristic of a lake system. Sedimentation of inorganic particulate is low. Light penetration is sufficient to promote primary production, with nutrient levels the limiting factor and production of organic matter exceeds decomposition within the mixed layer. Entrainment of metalimnetic and hypolimnetic water, particulates, and nutrients may occur through internal waves or wind mixing during the passage of large weather fronts. Hypolimnetic mixing may be more extensive in reservoirs than "natural" lakes because of bottom withdrawal. In addition, an intake structure may simultaneously remove water from the hypolimnion and metalimnion.

When tributary inflow enters a reservoir, it displaces the reservoir water. If there is no density difference between the inflow and reservoir waters, the inflow will mix with the reservoir water as the inflow water moves toward the dam. However, if there are density differences between the inflow and reservoir waters, the inflow moves as a density current in the form of overflows, interflows, or underflows. Internal mixing is the term used to describe mixing within a reservoir from such factors as wind, Langmuir circulation, convection, Kelvin-Helmholtz instabilities, and outflow (USACE, 1987).

2.2 CHEMICAL CHARACTERISTICS OF RESERVOIR PROCESSES

2.2.1 CONSTITUENTS

Some of the most important chemical constituents in reservoir waters that affect water quality are needed by aquatic organisms for survival. These include oxygen, carbon, nitrogen, and phosphorus. Other important constituents are silica, manganese, iron, and sulfur.

Dissolved oxygen: Oxygen is a fundamental chemical constituent of waterbodies that is essential to the survival of aquatic organisms and is one of the most important indicators of reservoir water quality conditions. The distribution of dissolved oxygen (DO) in reservoirs is a result of dynamic transfer processes from the atmospheric and photosynthetic sources to consumptive uses by the aquatic biota. The resulting distribution of DO in the reservoir water strongly affects the solubility of many inorganic chemical constituents. Often, water quality control or management approaches are formulated to maintain an aerobic, or oxic (i.e., oxygen-containing), environment. Oxygen is produced by aquatic plants (phytoplankton and macrophytes) and is consumed by aquatic plants, other biological organisms, and chemical oxidations. In reservoirs, the DO demand may be divided into two separate but highly interactive fractions: sediment oxygen demand (SOD) and water column oxygen demand.

Sediment oxygen demand: The SOD is typically highest in the upstream area of the reservoir just below the headwaters. This is an area of transition from riverine to lake characteristics. It is relatively shallow but stratifies. The loading and sedimentation of organic matter is high in this transition area and, during stratification, the hypolimnetic DO to satisfy this demand can be depleted. If anoxic conditions develop, they generally do so in this area of the reservoir and progressively move toward the dam during the stratification period. The SOD is relatively independent of DO when DO concentrations in the water column are greater than 3 to 4 mg/l but becomes limited by the rate of oxygen supply to the sediments.

Water column oxygen demand: A characteristic of many reservoirs is a metalimnetic minimum in DO concentrations, or negative heterograde oxygen curve (Figure 2-1). Density interflows not only transport oxygen-demanding material into the metalimnion but can also entrain reduced chemicals from the upstream anoxic area and create additional oxygen demand. Organic matter and organisms from the mixed layer settle at slower rates in the metalimnion because of increased

viscosity due to lower temperatures. Since this labile organic matter remains in the metalimnion for a longer time period, decomposition occurs over a longer time, exerting a higher oxygen demand. Metalimnetic oxygen depletion is an important process in deep reservoirs. A hypolimnetic oxygen demand generally starts at the sediment/water interface unless underflows contribute organic matter that exerts a significant oxygen demand. In addition to metalimnetic DO depletion, hypolimnetic DO depletion also is important in shallow, stratified reservoirs since there is a smaller hypolimnetic volume of oxygen to satisfy oxygen demands than in deeper reservoirs.

Dissolved oxygen distribution: Two basic types of vertical DO distribution may occur in the water column: an orthograde and clinograde DO distribution (Figure 2-1). In the orthograde distribution, DO concentration is a function primarily of temperature since DO consumption is limited. The clinograde DO profile is representative of more productive, nutrient-rich reservoirs where the hypolimnetic DO concentration progressively decreases during stratification and can occur during both summer and winter stratification periods.

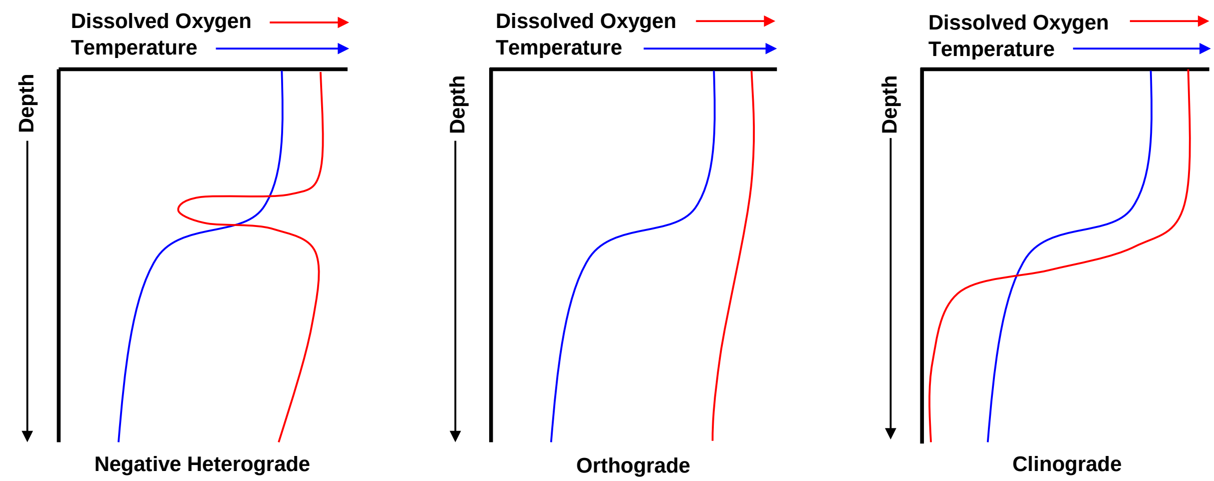


Figure 2-1. Vertical oxygen concentrations possible in thermally stratified lakes.

Inorganic carbon: Inorganic carbon represents the basic building block for the production of organic matter by plants. Inorganic carbon can also regulate the pH and buffering capacity or alkalinity of aquatic systems. Inorganic carbon exists in a dynamic equilibrium in three major forms: carbon dioxide (CO_2), bicarbonate ions (HCO_3), and carbonate ions (CO_3). Carbon dioxide is readily soluble in water and some CO_2 remains in a gaseous form, but the majority of the CO_2 forms carbonic acid that dissociates rapidly into HCO_3 and CO_3 ions. This dissociation results in a weakly alkaline system (i.e., pH ≈ 7.1 or 7.2). There is an inverse relationship between pH and CO_2. The pH increases when aquatic plants (phytoplankton or macrophytes) remove CO_2 from the water to form organic matter through photosynthesis during the day. During the night when aquatic plants respire and release CO_2, the pH decreases. The extent of this pH change provides an indication of the buffering capacity of the system. Weakly buffered systems with low alkalinities (i.e., <500 microequivalents per liter) experience larger shifts in pH than well-buffered systems (i.e., >1,000 microequivalents per liter).

Nitrogen: Nitrogen is important in the formulation of plant and animal protein. Nitrogen, similar to carbon, also has a gaseous form. Many species of cyanobacteria can use or fix elemental or gaseous N_2 as a nitrogen source. The most common forms of nitrogen in aquatic systems are ammonia (NH_3-N), nitrite (NO_2-N), and nitrate (NO_3-N). All three forms are transported in water in a dissolved phase. Ammonia results primarily from the decomposition of organic matter. Nitrite is primarily an intermediate compound in the oxidation or nitrification of ammonia to nitrate, while nitrate is the stable oxidation state of nitrogen and represents the other primary inorganic nitrogen form, besides NH_3, used by aquatic plants.

Phosphorus: Phosphorus is used by both plants and animals to form enzymes and vitamins and to store energy in organic matter. Phosphorus has received considerable attention as the nutrient controlling algal production and densities and associated water quality problems. The reasons for this emphasis are: phosphorus tends to limit plant growth more than the other major nutrients; phosphorus does not have a gaseous phase and ultimately originates from the weathering of rocks; removal of phosphorus from point sources can reduce the growth of aquatic plants; and the technology for removing phosphorus is more advanced and less expensive than nitrogen removal. Phosphorus is generally expressed in terms of the chemical procedures used for measurement: total phosphorus, particulate phosphorus, dissolved or filterable phosphorus, and soluble reactive phosphorus. Phosphorus is a very reactive element; it reacts with many cations such as iron and calcium and is readily sorbed on particulate matter such as clays, carbonates, and inorganic colloids. Since phosphorus exists in a particulate phase, sedimentation represents a continuous loss from the water column to the sediment. Sediment phosphorus, then, may exhibit longitudinal gradients in reservoirs similar to sediment silt/clay gradients. Phosphorus contributions from sediment under anoxic conditions and macrophyte decomposition are considered internal phosphorus sources or loads, and are in a chemical form readily available for plankton uptake and use. Internal phosphorus loading can represent a major portion of the total phosphorus budget.

Silica: Silica is an essential component of diatom algal frustules or cell walls. Silica uptake by diatoms can markedly reduce silica concentrations in the epilimnion and initiate a seasonal succession of diatom species. When silica concentrations decrease below 0.5 mg/l, diatoms generally are no longer competitive with other phytoplankton species.

Other nutrients: Iron, manganese, and sulfur concentrations generally are adequate to satisfy plant nutrient requirements. Oxidized iron (III) and manganese (IV) are quite insoluble in water and occur in low concentrations under aerobic conditions. Under aerobic conditions, sulfur usually is present as sulfate.

2.2.2 ANAEROBIC (HYPOXIC AND ANOXIC) CONDITIONS

When dissolved oxygen concentrations are reduced to approximately 2 to 3 mg/l, the oxygen regime is considered hypoxic. Anoxic conditions occur when there is a complete lack of oxygen. When hypoxic conditions occur in the hypolimnion, the oxygen regime at the sediment/water interface is generally considered anoxic, and anaerobic processes begin to occur in the sediment interstitial water. Nitrate reduction to ammonium and/or N_2O or N_2 (denitrification) is considered to be the first phase of the anaerobic process and places the system in a slightly reduced electrochemical state. Ammonium-nitrogen begins to accumulate in the hypolimnetic water. The presence of nitrate prevents the production of additional reduced forms such as manganese (II), iron (II), or sulfide species. Denitrification probably serves as the main mechanism for removing nitrate from the hypolimnion. Following the reduction or denitrification of nitrate, manganese species are reduced from insoluble forms (i.e., Mn (IV)) to soluble manganous forms (i.e., Mn (II)), which diffuse into the overlying water column. Nitrate reduction is an important step in anaerobic processes since the presence of nitrate in the water column will inhibit manganese reduction. As the electrochemical potential of the system becomes further reduced, iron is reduced from the insoluble ferric (III) form to the soluble ferrous (II) form and begins to diffuse into the overlying water column. Phosphorus, in many instances, is also transported in a complexed form with insoluble ferric (III) species; therefore, the reduction and solubilization of iron also result in the release and solubilization of phosphorus into the water column. The sediments may serve as a major phosphorus source during anoxic periods and a phosphorus sink during aerobic periods. During this period of anaerobiosis, microorganisms also are decomposing organic matter into lower molecular weight acids and alcohols such as acetic, fulvic, humic, and citric acids and methanol. These compounds may also serve as trihalomethane precursors (low-molecular weight organic compounds in water; i.e., methane, formate acetate), which, when subject to chlorination during water treatment, form trihalomethanes, or THMs

(carcinogens). As the system becomes further reduced, sulfate is reduced to sulfide, which begins to appear in the water column. Sulfide will readily combine with soluble reduced iron (II), however, to form insoluble ferrous sulfide, which precipitates out of solution. If the sulfate is reduced to sulfide and the electrochemical potential is strongly reducing, methane formation from the reduced organic acids and alcohols may occur. Consequently, water samples from anoxic depths will exhibit these chemical characteristics.

Anaerobic processes are generally initiated in the upstream portion of the hypolimnion where organic loading from the inflow is relatively high and the volume of the hypolimnion is minimal, so oxygen depletion occurs rapidly. Anaerobic conditions are generally initiated at the sediment/water interface and gradually diffuse into the overlying water column and downstream toward the dam. Anoxic conditions may also develop in a deep pocket near the dam due to decomposition of autochthonous organic matter settling to the bottom. This anoxic pocket, in addition to expanding vertically into the water column, may also move upstream and eventually meet the anoxic zone moving downstream.

Anoxic conditions are generally associated with the hypolimnion, but anoxic conditions may occur in the metalimnion. The metalimnion may become anoxic due to microbial respiration and decomposition of plankton settling into the metalimnion, microbial metabolism of organic matter entering as an interflow, or entrainment of anoxic hypolimnetic water from the upper portion of the reservoir.

2.3 BIOLOGICAL CHARACTERISTICS AND PROCESSES

2.3.1 MICROBIOLOGICAL

The microorganisms associated with reservoirs may be categorized as pathogenic or nonpathogenic. Pathogenic microorganisms are of a concern from a human health standpoint and may limit recreational and other uses of reservoirs. Nonpathogenic microorganisms are important in that they often serve as decomposers of organic matter and are a major source of carbon and energy for a reservoir. Microorganisms generally inhabit all zones of the reservoir as well as all layers. Seasonally high concentrations of bacteria will occur during the warmer months, but they can be diluted by high discharges. Anaerobic conditions enhance growth of certain bacteria while aeration facilitates the use of bacterial food sources. Microorganisms, bacteria in particular, are responsible for mobilization of contaminants from sediments.

2.3.2 PHOTOSYNTHESIS

Oxygen is a by-product of aquatic plant photosynthesis, which represents a major source of oxygen for reservoirs during the growing season. Oxygen solubility is less during the period of higher water temperatures, and diffusion may also be less if wind speeds are lower during the summer than the spring or fall. Biological activity and oxygen demand typically are high during summer thermal stratification, so photosynthesis may represent a major source of oxygen during this period. Oxygen supersaturation in the euphotic zone can occur during periods of high photosynthesis.

2.3.3 PLANKTON

Phytoplankton influence dissolved oxygen and suspended solids concentrations, transparency, taste and odor, aesthetics, and other factors that affect reservoir uses and water quality objectives. Phytoplankton are a primary source of organic matter production and form the base of the autochthonous food web in many reservoirs since fluctuating water levels may limit macrophyte and periphyton production. Phytoplankton can be generally grouped as diatoms, green algae, cyanobacteria, or cryptomonad algae. Chlorophyll *a* represents a common variable used to estimate phytoplankton biomass.

Seasonal succession of phytoplankton species is a natural occurrence in reservoirs. The spring assemblage is usually dominated by diatoms and cryptomonads. Silica depletion in the photic zone and increased settling as viscosity decreases because of increased temperatures usually result in green algae succeeding the diatoms. Decreases in nitrogen or a decreased competitive advantage for carbon at higher pH may result in cyanobacteria succeeding the green algae during summer and fall. Diatoms generally return in the fall, but cyanobacteria, greens, or diatoms may cause algae blooms following fall turnover when hypolimnetic nutrients are mixed throughout the water column. The general pattern of seasonal succession of phytoplankton is fairly constant from year to year. However, hydrologic variability, such as increased mixing and delay in the onset of stratification during cool, wet spring periods, can maintain diatoms longer in the spring and shift or modify the successional pattern of algae in reservoirs.

Phytoplankton grazers can reduce the abundance of algae and alter their successional patterns. Some phytoplankton species are consumed and assimilated more readily and are preferentially selected by consumers. Single-celled diatom and green algae species are readily consumed by zooplankton, while filamentous cyanobacteria are avoided by zooplankters'. Altering the fish population can result in a change in the zooplankton population that can affect the phytoplankton population.

2.3.4 ORGANIC CARBON AND DETRITUS

Total organic carbon (TOC) is composed of dissolved organic carbon (DOC) and particulate organic carbon (POC). Detritus represents that portion of the POC that is nonliving. Nearly all the TOC of natural waters consists of DOC and detritus, or dead POC. The processes of decomposition and consumption of TOC are important in reservoirs and can have a significant effect on water quality.

DOC and POC are decomposed by microbial organisms. This decomposition exerts an oxygen demand that can remove dissolved oxygen from the water column. During stratification, the metalimnion and hypolimnion become relatively isolated from sources of dissolved oxygen, and depletion can occur through organic decomposition. There are two major sources of this organic matter: allochthonous (i.e., produced outside the reservoir and transported in) and autochthonous (i.e., produced within the reservoir). Allochthonous organic carbon in small streams may be relatively refractory since it consists of decaying terrestrial vegetation that has washed or fallen into the stream. Larger rivers, however, may contribute substantial quantities of riverine algae or periphyton that decompose rapidly and can exert a significant oxygen demand. Autochthonous sources include dead plankton settling from the mixed layers and macrophyte fragments and periphyton transported from the littoral zone. These sources are also rapidly decomposed.

POC and DOC absorbed onto sediment particles may serve as a major food source for aquatic organisms. The majority of the phytoplankton production enters the detritus food web with a minority being grazed by primary consumers (USACE, 1987). While autochthonous production is important in reservoirs, typically as much as three times the autochthonous production may be contributed by allochthonous material (USACE, 1987).

2.4 BOTTOM WITHDRAWAL RESERVOIRS

Bottom withdrawal reservoirs have outlet structures located near the deepest part of the reservoir. Bottom withdrawal removes hypolimnetic water and nutrients and may promote movement of interflows or underflow into the hypolimnion. They release cold water from the deep portion of the reservoir; however, this water may be hypoxic or anoxic during periods of stratification. Bottom outlets can cause density interflows or underflows (e.g., flow laden with sediment or dissolved solids) through the reservoir and generally provide little or no direct control over release water quality.

3 MAINSTEM SYSTEM WATER QUALITY MONITORING

3.1 MAINSTEM SYSTEM RESERVOIRS

3.1.1 LONG-TERM, FIXED-STATION AMBIENT MONITORING

The District conducts long-term, fixed-station ambient water quality monitoring at the six Mainstem System reservoirs. Recent ambient water quality monitoring has included monthly (May through September) monitoring at deepwater sites along the length of the reservoirs, and monthly (April through September) monitoring of major inflows. Recent locations monitored at Fort Peck Lake included three sites on the reservoir (near Fort peck Dam, RM1772; Hell Creek Bay, RM1805; and Rock Creek Bay, upper reaches of Dry Creek Arm) and the Missouri River inflow near Landusky, MT (RM1921). Recent locations monitored at Lake Sakakawea included five sites on the reservoir (near Garrison Dam, RM1390; Beulah Bay, RM1412; Deepwater Bay, RM1445; New Town, RM1481; and White Tail Bay, RM1512) and the Missouri River inflow near Williston, ND (RM1553). Recent locations monitored at Lake Oahe included five sites on the reservoir (near Oahe Dam, RM1073; Cheyenne River confluence, RM1110; Whitlocks Bay, RM11153; Mobridge, RM1196; and Beaver Creek RM1256) and the Missouri River inflow at Bismarck, ND (RM1315). Recent locations monitored at Lake Sharpe included three sites on the reservoir (near Big Bend Dam, RM987; South Iron Nation, RM1020, and Antelope Creek, RM1055). Recent locations monitored at Lake Francis Case included four sites on the reservoir (near Fort Randall Dam, RM880; Platte Creek, RM911; Elm Creek, RM940; and Chamberlain, RM968). Recent locations monitored at Lewis and Clark Lake included three sites on the reservoir (near Gavins Point Dam, RM811; Bloomfield, RM819; and Charley Creek RM825) and the Missouri River inflow at Running Water, SD (RM840). Water quality monitoring included field measurements and collection of surface water samples for analytical analysis. Field measurements included surface water transparency (i.e., Secchi depth) and measuring temperature, dissolved oxygen, pH, conductivity, oxidation-reduction potential (ORP), turbidity, and chlorophyll *a* at 1-meter increments from the reservoir surface to the bottom. Near-surface and near-bottom grab samples were collected and delivered to the laboratory where they were analyzed for various physicochemical and biological constituents.

3.1.2 BACTERIA MONITORING AT SWIMMING BEACHES

The District has cooperated with the Nebraska Department of Environmental Quality (NDEQ) to monitor bacteria levels present at swimming beaches at the Gavins Point project over the past 9 years. Five swimming beaches on Lewis and Clark Lake and one on Lake Yankton were monitored. Weekly grab samples were collected from May through September and analyzed for fecal coliform and *E. coli* bacteria and the cyanobacteria toxin microcystin. The bacteria monitoring was conducted to meet a 6-hour holding time for collected samples.

3.1.3 INTENSIVE WATER QUALITY SURVEYS

3.1.3.1 Lake Sharpe and Lewis and Clark Lake

The District completed the final year of planned 3-year intensive water quality surveys at Lake Sharpe and Lewis and Clark Lake in 2010. The monitoring objectives of the intensive surveys were to collect water quality data to spatially describe water quality conditions present in the reservoirs during the summer and to collect information to facilitate future application of the CE-QUAL-W2 hydrodynamic and water quality model. As part of the intensive surveys, additional reservoir and inflow sites were monitored.

3.1.3.2 Lower Missouri River

A planned 3-year intensive water quality survey of the lower Missouri River has initiated in 2010. The Omaha District is working with the Kansas City District to monitor the water quality conditions of the Missouri River downstream of Gavins Point Dam to St. Louis, MO. Monitoring includes water quality sampling of the Missouri River as well as major tributaries. Various physicochemical and biological constituents are being monitored to facilitate application of the CE-QUAL-W2 hydrodynamic and water quality model.

3.2 MAINSTEM SYSTEM POWERPLANTS

As part of the operation of the Mainstem System powerplants, water is drawn from the intake structure of each dam and piped through the powerplant in a “raw water” supply line that is tapped for various uses. The “raw water” supply line is an open-ended, flow-through system. A monitoring station, that measures water quality conditions of water drawn from near the start of the “raw water” supply line, has been irregularly maintained at each of the powerplants in the past. Recent water quality monitoring has consisted of year-round, hourly measurements of temperature and dissolved oxygen through the use of a data-logger. Monthly grab samples (year-round) have also been collected and analyzed for various physicochemical constituents. The rate of dam discharge when water quality sampling occurs is determined from powerplant records. The water quality conditions measured in the “raw water” supply lines of the Mainstem System powerplants are believed to represent the water quality conditions present in the reservoirs near the dam intakes and in the tailwaters (i.e., Missouri River) immediately downstream of the dam. The discharge from Oahe and Big Bend Dams is respectively taken to represent the Missouri River inflow to Big Bend and Fort Randall Reservoirs.

3.3 MISSOURI RIVER FROM FORT RANDALL DAM TO RULO, NE

Since 2003, the District has cooperated with the State of Nebraska (NDEQ) to monitor ambient water quality conditions along the Missouri River from Fort Randall Dam to Rulo, Nebraska. Fixed-station monitoring has occurred at the following ten sites: Fort Randall Dam tailwaters; near Verdel, NE; at Running Water, SD; Gavins Point Dam tailwaters; near Maskell, NE; near Ponca, NE; at Decatur, NE; at Omaha, NE; at Nebraska City, NE; and at Rulo, NE. Water quality monitoring consisted of collecting monthly near-surface grab samples year-round. The collected grab samples were analyzed for various physicochemical and biological constituents, and various field measurements were also taken.

3.4 MAINSTEM SYSTEM ANCILLARY LAKES – LAKE YANKTON, LAKE POCASSE, AND LAKE AUDUBON

Lake Yankton, Lake Pocasse, and Lake Audubon are ancillary lakes to the Mainstem System reservoirs located respectively at the Gavins Point, Oahe, and Garrison projects. Water quality monitoring at these three lakes has been sporadic in the past. The Omaha District initiated ambient water quality monitoring at the lakes in 2006 as part of a 3-year rotational monitoring cycle. All three lakes were monitored in 2009. Monitoring at the three lakes included monthly monitoring (May through September) at a near-dam deepwater location. The monitoring includes field measurements for depth profiling and water transparency and collection of near-surface and near-bottom water samples for laboratory analysis. Near-surface and near-bottom grab samples are analyzed for various physicochemical and biological constituents.

4 WATER QUALITY ASSESSMENT METHODS

4.1 EXISTING WATER QUALITY

For the purposes of this report, existing water quality is defined as water quality conditions that occurred during the past 5 years (i.e., 2006 through 2010). Water quality monitoring conducted during this period was used to describe existing water quality conditions.

4.1.1 STATISTICAL SUMMARY AND COMPARISON TO APPLICABLE WATER QUALITY STANDARDS CRITERIA

Statistical analyses were performed on the surface water quality monitoring data collected at the Mainstem System reservoirs (including inflow and outflow sites), powerplants, on the Missouri River, and at the Mainstem System ancillary lakes. Descriptive statistics were calculated to describe central tendencies and the range of observations in existing water quality. Monitoring results were compared to applicable water quality standards criteria established by the appropriate States pursuant to the Federal Clean Water Act. Tables were constructed that list the parameters measured; number of observations; and the mean, median, minimum, and maximum of the data collected. The constructed Tables also list the water quality standards criteria applicable to the individual parameters and the frequency that these criteria were not met.

4.1.2 SPATIAL VARIATION IN WATER QUALITY CONDITIONS

4.1.2.1 Longitudinal Variation

4.1.2.1.1 Reservoir Contour Plots

Longitudinal contour plots were developed for all six Mainstem System reservoirs. Contour plots were constructed for temperature, dissolved oxygen, and turbidity from depth-profile measurements collected along the length of the reservoirs. The longitudinal contour plots were constructed using the "Hydrologic Information Plotting Program" included in the "Data Management and Analysis System for Lakes, Estuaries, and Rivers" (DASLER-X) software developed by HydroGeoLogic Inc. (HydroGeoLogic Inc., 2005).

4.1.2.1.2 Reservoir Box Plots

Longitudinal box plots were developed for all six Mainstem System reservoirs from measurements collected along the length of the reservoir. When significant variation in measured parameters was observed along the length of the reservoir, box plots were constructed to display longitudinal variation.

4.1.2.1.3 Lower Missouri River Box Plots

Longitudinal box plots were constructed for the lower Missouri River from Gavins Point Dam to Rulo, NE. The box plots were constructed from the water quality monitoring conducted in cooperation with the NDEQ during the period 2006 through 2010. The box plots are oriented to display the measured change in selected water quality parameters along the Missouri River downstream of Gavins Point Dam.

4.1.2.2 <u>Vertical Variation</u>

4.1.2.2.1 Reservoir Water Quality

Depending on bathymetry and location, lakes can experience thermally-induced density stratification in the summer. This can lead to significant vertical water quality variation if anoxic or near-anoxic conditions develop in the hypolimnion.

4.1.2.2.1.1 Summer Depth-Profile Plots

Measured water temperature and dissolved oxygen depth profiles were plotted for the Mainstem System reservoirs and Mainstem System ancillary lakes. The plotted depth profiles were measured at the near-dam, deepwater ambient monitoring location. Depth profiles measured in the months of July, August, and September over the past 5 years were plotted. The plots were reviewed to assess the occurrence of thermal stratification and hypolimnetic dissolved oxygen degradation.

4.1.2.2.1.2 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

The variation of selected parameters with depth was evaluated by comparing paired near-surface and near-bottom collected samples. The paired samples compared were collected at the near-dam, deepwater monitoring location over the past 5 years. The parameters compared included water temperature, dissolved oxygen, ORP, pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen, total ammonia, and total phosphorus. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements, and a paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different (α = 0.05).

4.1.2.2.2 Missouri River Water Quality

It is recognized that the concentrations of particulate-associated constituents (e.g., total suspended solids, total suspended sediment, total phosphorus, total organic carbon, etc.) can vary from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Thus, sampling of water quality conditions near the surface of a river could under estimate the “true” water-column composite concentration for these constituents. However, the sinking effect, especially for “lighter” material, can be reduced by resuspension if current velocity and turbulence are significant.
To assess this situation and to facilitate application of the CE-QUAl-W2 hydrodynamic and water quality model, depth-profile measurements and depth-discrete samples were collected in 2010 at Missouri River inflow sites to the Mainstem System reservoirs and along the lower Missouri River downstream of Gavins Point Dam.

4.1.2.2.2.1 Depth-Profile Plots

Measured water temperature, dissolved oxygen, pH, conductivity, turbidity, and chlorophyll *a* depth profiles were plotted for the Missouri River at monitoring sites where depth-profile measurements were collected. The plotted depth profiles were measured in the deepest area of the river thalweg based on electronic sounding equipment. Depth profiles measured monthly (April through October) were plotted by constituent and the river flow at the time of the profile measurement was annotated. The plots were reviewed to assess variation with depth.

4.1.2.2.2.2 Comparison of Near-Surface, Mid-Depth, and Near-Bottom Water Quality Conditions

The variation of particulate-associated constituents (i.e., total suspended solids, total suspended sediment, total phosphorus, total organic carbon, and total Kjeldahl nitrogen) and non-particulate associated constituents (i.e., temperature, total dissolved, solids, dissolved sulfate, and dissolved phosphorus) with depth was evaluated by comparing paired near-surface, mid-depth, and near-bottom collected samples. The paired samples compared were collected in the deepest area of the river thalweg based on electronic sounding equipment. Box plots were constructed to display the distribution of the paired near-surface, mid-depth, and near-bottom measurements, and a paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$).

4.1.3 TEMPORAL VARIATION IN WATER QUALITY CONDITIONS

4.1.3.1 Time Series Plots of Mean Daily Water Temperatures Measured in the Missouri River Upstream and Downstream of the Mainstem System Reservoirs

Annual seasonal time series plots of mean daily water temperatures measured in the Missouri River immediately upstream and downstream of the Mainstem System reservoirs were constructed to display temporal and spatial variation. These plots also give an indication of how the thermal regime of the Missouri River is impacted by the reservoir.

4.1.3.2 Time-Series Plots of Flow, Water Temperature, and Dissolved Oxygen of Water Discharged through the Mainstem System Dams

Time series plots were prepared for water quality conditions monitored at the Missouri River Mainstem System powerplants during the 5-year period 2006 through 2010. Semi-annual plots of hourly water temperature, dissolved oxygen, and dam discharge were constructed. Water temperature and dissolved oxygen plots represent monitoring of water drawn from the "raw water" supply line in each powerplant.

4.1.4 TROPHIC STATUS

A Trophic State Index (TSI) was calculated, as described by Carlson (1977). TSI values were determined from Secchi depth transparency, total phosphorus, and chlorophyll *a* measurements. Values for these three parameters were converted to an index number ranging from 0 to 100 according to the following equations:

$$\text{TSI(Secchi Depth)} = \text{TSI(SD)} = 10[6 - (\ln \text{SD}/\ln 2)]$$
$$\text{TSI(Chlorophyll } a\text{)} = \text{TSI(Chl)} = 10[6 - ((2.04\text{-}0.68 \ln \text{Chl})/\ln 2)]$$
$$\text{TSI(Total Phosphorus)} = \text{TSI(TP)} = 10[6 – (\ln (48/\text{TP})/\ln 2)]$$

Accurate TSI values from total phosphorus depend on the assumptions that phosphorus is the major limiting factor for algal growth and that the concentrations of all forms of phosphorus present are a function of algal biomass. Accurate TSI values from Secchi depth transparency depend on the assumption that water clarity is primarily limited by phytoplankton biomass. Carlson indicates that the chlorophyll TSI value may be a better indicator of a lake's trophic conditions during mid-summer when algal productivity is at its maximum, while the total phosphorus TSI value may be a better indicator in the spring and fall when algal biomass is below its potential maximum. Calculation of TSI values from data collected from a lake's epilimnion during summer stratification provide the best agreement between all of the index parameters and facilitate comparisons between lakes. A TSI average value, calculated as the

average of the three individually determined TSI values, is used by the District as an overall indicator of a reservoir's trophic state. The District uses the criteria defined in Table 4-1 for determining lake trophic status from TSI values.

Table 4-1. Lake trophic status based on calculated TSI values.

TSI	Trophic Condition
0-35	Oligotrophic
36-50	Mesotrophic
51-55	Moderately Eutrophic
56-65	Eutrophic
66-100	Hypereutrophic

4.1.5 MAINSTEM SYSTEM RESERVOIR PLANKTON COMMUNITY

4.1.5.1 Phytoplankton

Assessment of the phytoplankton community was based on grab samples that were analyzed by a contract laboratory. Grab samples were collected at a depth of one-half the measured Secchi depth. Laboratory analyses consisted of identification of phytoplankton taxa to the lowest practical level and quantification of taxa biovolume. These results were used to determine the relative abundance of phytoplankton taxa at the division level based on the measured biovolumes.

4.1.5.2 Zooplankton

Zooplankton sampling was re-initiated in 2010. Assessment of the zooplankton community was based on vertical-tow samples collected from near the reservoir bottom to the surface. Laboratory analyses consisted of identification of zooplankton taxa to the lowest practical level and quantification of taxa biomass. These results were used to determine the relative abundance of zooplankton taxa at the division level based on the measured biomasses.

4.1.6 IMPAIRMENT OF DESIGNATED WATER QUALITY-DEPENDENT BENEFICIAL USES

Water quality-dependent beneficial uses are designated to waterbodies in State water quality standards and criteria are defined to protect these uses. Water quality data collected by the District during the 5-year period 2006 through 2010 were assessed to determine if water quality conditions were impairing the designated beneficial uses. These data were assessed using the methodologies defined by the appropriate States in developing their latest Integrated Water Quality Reports pursuant to the Federal Clean Water Act (CWA). It is noted that the "official" determination of whether water quality-dependent beneficial uses are impaired, pursuant to the CWA, is by the States pursuant to their Section 305(b) and Section 303(d) assessments compiled in their biennial Integrated Water Quality Reports (See Table 1-3).

4.1.6.1 Montana Assessment Methodologies

The State of Montana requires that beneficial use support determinations be based on sufficient and credible data. Once sufficient and credible data are established, use support determinations are made based on defined assessment criteria (MDEQ, 2006). Assessment criteria for aquatic life, drinking water, and recreation use support applicable to water quality monitoring data collected by the District are given in Table 4-2, Table 4-3, and Table 4-4.

Table 4-2. Aquatic life use support assessment criteria defined by Montana and applicable to data collected by the District.

Data Type	Beneficial Use Impairment: Unimpaired or Least Impaired	Moderately Impaired	Severely Impaired
Chemical Toxicants (i.e., Trace Metals and Ammonia)	• No exceedance of acute water quality standard. • Exceedances of chronic water quality standard ≤10% (no more than once for one parameter in a 3-year period when measurements were taken at least 4 times/year).	• Exceedances of acute water quality standard 1 to 25%. • Exceedances of chronic water quality standard 11 to 50%. • Exceedances of chronic water quality standard 1 to 10% of a "large" data set.	• Exceedances of acute water quality standard >25%. • Exceedances of chronic water quality standard >50%. • Exceedances of chronic water quality standard >10% of a "large" data set.
Trophic Status	Trophic status is similar to reference conditions.	Trophic status exceeds reference conditions.	Trophic status is hypereutrophic.
Chemistry (i.e., Nutrients, D.O., pH, TSS, Turbidity, Temp.)	Exceedances of water quality standard ≤10% of a "large" data set.	Exceedances of water quality standard 11 to 25% of a "large" data set.	Exceedances of water quality standard >25% of a "large" data set.
Nutrients	Nutrient concentrations are similar to reference conditions.	Nutrient concentrations are moderately higher than reference conditions.	Nutrient concentrations are substantially higher then reference conditions.
Biological Assemblage (i.e., Phytoplankton)	Data indicate functioning sustainable biological assemblage (>75% of reference condition).	Data indicate moderate impairment (25 to 75% of reference condition).	Data indicate severe impairment (<25% of reference condition).
Chlorophyll a	The chlorophyll levels are similar to reference conditions.	The chlorophyll level is moderately higher than reference condition.	The chlorophyll level is substantially greater than reference condition

Table 4-3. Drinking water use support assessment criteria defined by Montana and applicable to data collected by the District.

Data Type	Beneficial Use Impairment: Unimpaired or Least Impaired	Moderately Impaired	Severely Impaired
Chemistry (i.e., Inorganics, Organics)	No human health standard exceedances.	Not applicable.	Exceedance of human health standards.

Table 4-4. Recreation use support assessment criteria defined by Montana and applicable to data collected by the District.

Data Type	Beneficial Use Impairment: Unimpaired or Least Impaired	Moderately Impaired	Severely Impaired
Algae, Toxins, etc.	There are no excessive algae blooms, turbidity, odor, toxins, etc.; similar to reference conditions.	Excessive algae blooms, turbidity, odor, toxins, etc. moderately restrict swimming or boating.	Swimming or boating severely inhibited by excessive algae blooms, pathogens, turbidity, odor, toxins, etc.
Chlorophyll a	The benthic chlorophyll level is similar to reference condition; or the chlorophyll is <50 mg/m^2.	The benthic chlorophyll level moderately exceeds reference condition; or the chlorophyll is 50 to 100 mg/m^2.	The benthic chlorophyll level greatly exceeds reference condition; or the chlorophyll is >100 mg/m^2.

4.1.6.2 Nebraska Assessment Methodologies

4.1.6.2.1 Assessment of Physicochemical Data

Nebraska water quality standards define acute and chronic numeric criteria for the protection of aquatic life and maximum criteria for the protection of public drinking and agricultural water supplies. Nebraska deems a designated use to be impaired if measured water quality conditions indicate that numeric criteria are exceeded more than 10 percent of the time over an assessed 5-year period (NDEQ, 2009). To address the uncertainty associated with water quality data, the application of the 10 percent exceedance criterion is based on the number of measurements for the appropriate water quality criteria. Table 4-5 gives the Nebraska assessment measures regarding sample size and the number of exceedances that indicate an impaired use (i.e., 10% exceedance) at a 90% confidence level (i.e., $\alpha = 0.10$). Consistent with U.S. Environmental Protection Agency (EPA) guidance, the assessment of toxic ("priority") pollutants will consider a waterbody impaired for aquatic life if an acute criteria for a toxic pollutant is exceeded more than once every 3 years on average.

Table 4-5. State of Nebraska Assessment Measures for Sample Size and Number of Exceedances Required to Determine an Impaired Use (i.e., 10% Exceedance).

Sample Size (n)	Number of Observations Exceeding a Criterion Required to Define an Impaired Use	Sample Size (n)	Number of Observations Exceeding a Criterion Required to Define an Impaired Use
<12	3	56 - 63	10
12 – 18	4	64 - 71	11
19 - 25	5	72 - 79	12
26 - 32	6	80 - 88	13
33 - 40	7	89 - 96	14
41 - 47	8	97 - 100	15
48 - 55	9	>100	Not Defined

4.1.6.2.2 Assessment of Fecal Coliform and *E. coli* Bacteria Data

Table 4-6 summarizes the Nebraska measures for the assessment of the Primary Contact Recreation Beneficial Use using fecal coliform and *E. coli* bacteria data.

Table 4-6. State of Nebraska measures for the assessment of the Primary Contact Recreation Beneficial Use using fecal coliform and *E. coli* bacteria data.

Parameter	Water Quality Criteria (Geometric Mean)	Supported	Impaired
Fecal Coliform	≤ 200cfu/100ml	Season geometric mean ≤ 200cfu/100ml	Season geometric mean > 200cfu/100ml
E. coli	≤ 126cfu/100ml	Season geometric mean ≤ 126cfu/100ml	Season geometric mean > 126cfu/100ml

4.1.6.2.3 Assessment of Cyanobacteria Toxins

Table 4-7 summarizes the Nebraska measures for the assessment of the Primary Contact Recreation Beneficial Use using cyanobacteria toxins data.

Table 4-7. State of Nebraska measures for the assessment of the Primary Contact Recreation Beneficial Use using cyanobacteria toxins data.

Supported	Impaired
≤ 10% of samples exceed 20 ug/l	> 10% of samples exceed 20 ug/l

4.1.6.2.4 Assessment of Reservoir Sedimentation

It is the State of Nebraska's position that excess sediment delivered to a lake can cause several problems including "objectionable colors, turbidity, and deposits." Deposition of sediment can displace or eliminate fish spawning and rearing and other aquatic habitats. Also, the recreation area of a lake can be reduced or rendered undesirable. Nebraska uses two measurements to assess lake sedimentation regarding the use of aesthetics: impoundment volume loss and sedimentation rate. Both the lake volume loss and sedimentation rate are based on the "as-built" conditions of the lake. Table 4-8 summarizes the Nebraska criteria for the assessment of lakes regarding sedimentation.

Table 4-8. State of Nebraska measures for the assessment of lake sedimentation data.

Minimum Assessment Period	Supported	Impaired
≥5 Years	Volume loss < 25%, and Annual sedimentation rate ≤0.75%	Volume loss ≥ 25%, and Annual sedimentation rate >0.75%

4.1.6.2.5 Assessment of Reservoir Nutrient Data

A meeting between EPA and NDEQ was held on August 25, 2009 to establish mutually agreeable nutrient and chlorophyll targets for Beneficial Use Support assessments to be reported in the 2010 Integrated Report. Resulting from this meeting were total phosphorus, total nitrogen, and chlorophyll targets for two regions of the state for the protection of aquatic life. The criteria that apply all the Corps reservoirs in the Omaha District are chlorophyll *a* 10 ug/l, total nitrogen 1 mg/l, and total phosphorus 50 ug/l. The data requirements for assessing nutrient data include:

- The established targets will apply to lake growing season conditions which is defined as being from May 1 through September 30 and data outside this date range will not be used in Beneficial Use Support assessments.
- Data must represent epilimnetic conditions in the lake or reservoir.
- While there are no spatial requirements for the data, the data must be representative of lake or reservoir conditions.
- An adequate dataset will contain 10 samples collected over two growing seasons, preferably five samples from each year.
- All valid data must have met NDEQ Quality Assurance/Quality Control requirements.

Total phosphorus, total nitrogen, and chlorophyll targets will be evaluated independently by comparing them to growing season mean concentrations. If growing season mean concentrations exceed any of the three targets, an impaired status to the Aquatic Life Use will be noted and the cause of this impairment will be listed as "nutrients". While the criteria described above will be used for Section 303(d) nutrient listings in the 2010 Integrated Report, future listings and de-listings of lakes and reservoirs for nutrients will be based on methodologies, targets and/or water quality standards that are applicable to that assessment cycle.

4.1.6.3 North Dakota Assessment Methodologies

Water quality standards are the fundamental benchmarks North Dakota uses to assess surface water quality and determine beneficial use impairment status (NDDH, 2010). North Dakota requires that beneficial use assessments be based on sufficient and credible data. The State criteria for sufficient and credible chemical, physical, and biological data are given in Table 4-9.

Table 4-9. State of North Dakota criteria for determining if data are sufficient and credible data for beneficial use impairment assessments.

• Data collection and analysis followed known and documented quality assurance/quality control procedures.
• Water column chemical or biological data are 10 years old or less for rivers, streams, lakes, and reservoirs; unless there is adequate justification to use older data (e.g., land use, watershed, or climatic conditions have not changed). Data for all 10 years of the period are not required to make an assessment.
• There are a minimum of 10 chemical samples collected in the 10-year period for rivers and streams. The 10 samples may range from one sample collected in each of 10 years or 10 samples collected all in 1 year.
• There should be a minimum of two samples collected from lakes or reservoirs collected during the growing season, May through September. The samples may consist of two samples collected the same year or samples collected in separate years.
• For all criteria that are expressed as a 30-day arithmetic average (e.g., chloride, sulfate, etc.) a minimum of four daily samples must be collected during any consecutive 30-day period. Samples collected during the same day shall be averaged and treated as one daily sample.
• There are situations where a single set of data is all that is needed to make a use support determination. For example, a single set of water chemistry data may be sufficient to establish that a waterbody is not supporting aquatic life use. In such situations where a single data set irrefutably proves that impairment exists, an impairment determination may be based on this "overwhelming evidence." Data cannot be overwhelming evidence unless the methods used for collection and analysis meets the most stringent standards for reliability and validity. It must be certain that the data are representative of actual current waterbody conditions. The data must be representative of the spatial extent of the waterbody and of relevant temporal patterns. Data more than 3 or 4 years old should not be used as overwhelming evidence unless there is a strong basis for concluding that conditions have not changed since the data were collected.

4.1.6.3.1 Assessment of Beneficial Use Support for Aquatic Life Based on Physicochemical Data

In general, aquatic life use determinations utilizing chemical data are based on the number of exceedances of the current State water quality standards criteria for dissolved oxygen, pH, and temperature; and on the number of exceedances of the acute or chronic standards for ammonia, aluminum, arsenic, cadmium, chromium, copper, cyanide, lead, nickel, selenium, silver, and zinc. The acute and chronic water quality standards criteria for trace metals are expressed as total recoverable metals and not as dissolved metals. However, where dissolved metals data are available, use support assessments are made by applying the dissolved metals data to the water quality standards criteria expressed as the total recoverable fraction. Table 4-10 gives the decision criteria that North Dakota uses to assess aquatic life use support based on physicochemical data.

Table 4-10. Aquatic life use support decision criteria defined by North Dakota for physicochemical data.

Aquatic Life Use Support	Criteria for Determining Use Support
Full Support	• Dissolved oxygen (DO) and pH: DO criterion of 5 mg/l (daily minimum) and pH criteria of 7 and 9 S.U. (daily minimum and maximum) not exceeded or exceeded in <10% of the samples and there is no record of lethality to aquatic biota. • Temperature: Daily maximum criterion of 29.4°C (85°F) not exceeded. • Ammonia and other toxic pollutants (i.e., trace elements and organics): Acute or chronic criterion is not exceeded during any consecutive 3-year period.
Full Support but Threatened	• DO and pH: One or more criteria exceeded in 11 to 25% of the samples. • Temperature: Daily maximum criterion exceeded in <10% of the samples. • Ammonia and other toxic pollutants (i.e., trace elements and organics): Acute or chronic criterion exceeded once or twice during any consecutive 3-year period.
Non Support	• DO and pH: One or more criteria exceeded in >25% of the samples. • Temperature: Daily maximum criterion exceeded in >10% of the samples. • Ammonia and other toxic pollutants (i.e., trace elements and organics): Acute or chronic criterion exceeded three or more times during any consecutive 3-year period.

4.1.6.3.2 Assessment of Beneficial Use Support for Aquatic Life and Recreation Based on Lake Trophic Data

Trophic status is used to assess whether aquatic life and recreation use of a lake is impaired. Under the North Dakota use assessment methodology, it is assumed hypereutrophic lakes do not fully support a sustainable sport fishery and are limited in recreational uses, whereas mesotrophic lakes fully support both aquatic life and recreation use. Eutrophic lakes may be assessed as fully supporting, fully supporting but threatened, or not supporting their uses for aquatic life or recreation. North Dakota further assesses eutrophic lakes based on: 1) the lake's water quality standards fishery classification; 2) information provided by North Dakota Game and Fish Department Fisheries Division staff, local water resource managers, and the public; 3) the knowledge of land use in the lake's watershed; and/or 4) the relative degree of eutrophication. For example, a eutrophic lake, which has a well-balanced sport fishery and experiences infrequent algal blooms, is assessed as fully supporting with respect to aquatic life and recreation use. A eutrophic lake, which experiences periodic algal blooms and limited swimming use, would be assessed as not supporting recreation use. A lake fully supporting its aquatic life and/or recreation use, but for which monitoring has shown a decline in its trophic status (i.e., increasing phosphorus concentrations over time), would be assessed as fully supporting but threatened.

Carlson's Trophic State Index (TSI) is used to assess lake trophic status. When conducting an aquatic life and recreation use assessment for a lake, the average TSI score should be calculated for each indicator (i.e., chlorophyll *a*, Secchi depth, and total phosphorus). If TSI scores for each indicator result in a different trophic status assessment, the assessment should be based first on the chlorophyll *a*, followed by the Secchi depth transparency. Only when there are not adequate chlorophyll *a* and/or Secchi depth data available to make an assessment should total phosphorus concentration data be used.

4.1.6.3.3 Assessment of Beneficial Use Support for Drinking Water

North Dakota's water quality standards define drinking water as "waters that are suitable for use as a source of water supply for drinking and culinary purposes, after treatment to a level approved by the North Dakota Department of Health". While most lakes and reservoirs are assigned this use, few currently are used as a drinking water supply; however, the District's Lake Sakakawea is used as a

drinking water supply. Drinking water use is assessed by comparing ambient water quality data to the State water quality standards criteria for chloride, sulfate, nitrate, and to the defined human health criteria. The decision criteria used by North Dakota to make beneficial use determinations are given in Table 4-11.

Table 4-11. Drinking water use support decision criteria defined by North Dakota.

Aquatic Life Use Support	Criteria for Determining Use Support
Full Support	No exceedances of the water quality standard criterion for nitrate, one or fewer exceedances of the 30-day average criteria for chloride or sulfate, and no exceedances of any of the human health standards.
Full Support but Threatened	The fully supporting, but threatened use assessment designation is not applied to the drinking water use. Waters are either assessed as fully supporting or not supporting based on chemical data applied to the numeric standards.
Non Support	One or more exceedances of the water quality criterion for nitrate, two or more exceedances of the 30-day average criteria for chloride or sulfate, or one or more exceedances of any of the human health criteria.

4.1.6.4 South Dakota Assessment Methodologies

The State of South Dakota requires that beneficial use support determinations be based on sufficient and credible data. Data must meet QA/QC requirements that assure data are representative. The decision criteria regarding data age, sample size, and exceedances that the State of South Dakota uses to determine beneficial use support are given in Table 4-12, Table 4-13, and Table 4-14.

Table 4-12. Data age requirements specified by South Dakota to consider data representative of actual conditions.

Description	Criteria Used
CONVENTIONAL PARAMETRS (e.g., dissolved oxygen, total suspended solids, pH, temperature, fecal coliform bacteria, etc.) TOXIC PARAMETERS (e.g., metals, ammonia, etc.)	• STREAMS: Data must be less than 5 years old. • LAKES: Data must be less than 10 years old. Unless there is justification that data is (or is not) representative of current conditions.

Table 4-13. Sample size requirements specified by South Dakota to consider data representative of actual conditions.

Description	Criteria Used
CONVENTIONAL PARAMETERS (e.g., DO, TSS, pH, temperature, fecal coliform bacteria, etc.)	• STREAMS: At least 20 samples for any one parameter are usually required at any site. The sample threshold is reduced to 10 samples if 3 or more samples exceed daily maximum water quality standards. • LAKES: At least two independent years of sample data and at least two sampling events per year.
TOXIC PARAMETERS (e.g., metals, ammonia, etc.)	• STREAMS: At least one water quality sampling event. • LAKES: At least one fish flesh sampling event. More than one exceedance of toxic criteria within the past 3 years.

Table 4-14. Decision criteria for beneficial use support determination identified by South Dakota.

Description	Criteria
CONVENTIONAL PARAMETERS (e.g., DO, TSS, pH, temperature, fecal coliform bacteria, etc.) Required percentage of samples exceeding water quality standards to consider segment water quality-limited.	STREAMS: >10% (or 3 or more exceedances between 10 and 19 samples) for daily maximum criteria. >10% (2 or more exceedances between 2 and 19 samples) for 30-day average criteria. LAKES: >10% exceedances when 20 or more samples are available. If <20 samples available, 3 exceedances are considered impaired. If one surface exceedance was observed for water temperature, DO, or pH; lake profile data is used to make use support determination. Lakes are considered fully supporting the aquatic life beneficial use if profile data indicate a region within the water column where temperature, pH, and dissolved oxygen meet numeric water quality standards criteria. If a region does not exist, the lake is listed for the parameter in exceedance.
TOXIC PARAMETERS (e.g., metals, ammonia, etc.) Required percentage of samples exceeding water quality standards to consider segment water quality-limited.	STREAMS: More than one exceedance of toxic criteria within the past 3 years for both the acute and chronic standard. LAKES: If flesh samples are above the Federal Drug Administration's recommended action levels (such as 1 part per million for mercury).

4.2 WATER QUALITY TRENDS

Surface water quality trends were assessed for water clarity (i.e. Secchi depth), total phosphorus, chlorophyll *a*, and calculated average TSI from monitoring results obtained at long-term, fixed-station ambient monitoring sites. Scatter plots were prepared by plotting the four parameters over the time period 1980 through 2010. A linear regression trend line was also plotted. Analysis of variance (ANOVA) was used to determine an R^2 value and to test for the significance ($\alpha = 0.05$) of a linear trend over time.

4.3 FISH TISSUE

Fish are capable of accumulating many toxic substances in excess of 1,000 times the concentrations found in surface waters. Subsequently, fish tissue analyses may provide information concerning the presence of toxicants in a waterbody that may not be detected through either water or sediment samples. Because of this, fish tissue monitoring is an excellent early indicator of potential toxic problems in surface waters. Different tissue types in fish (e.g., muscle, bone, organ, skin, adipose, etc.) tend to accumulate toxicants at different rates. Therefore, when used as an indicator, fish tissue analysis typically uses whole fish samples – a combination of all tissue types. The analysis of fish fillets for toxicants is typically used to determine the suitability of fish for human consumption. The public has expressed concerns on whether fish caught at District Projects are safe to consume. It is important that answers to public health concerns be based on substantiated knowledge of toxicants in fish fillets and the public health risks associated with measured toxicant concentrations. This type of information can be used by Tribes and States when considering the issuance of fish consumption advisories.

The District, at this time, does not collect fish tissue data at the Mainstem System Projects. However, all of the States in the District are currently implementing monitoring programs that include fish tissue sampling at the Mainstem System Projects. The District defers to the Tribes and States regarding ambient fish tissue monitoring and the issuance of fish consumption advisories. Advisories that have been issued by the appropriate Tribes and States and are in affect at the Mainstem System Projects are listed in Table 1-3.

5 MAINSTEM SYSTEM RESERVOIRS

5.1 BACKGROUND INFORMATION

The Mainstem System is comprised of six dams and reservoirs constructed by the Corps on the Missouri River and, where present, the free-flowing Missouri River downstream of the dams. The six dams and reservoirs in an upstream to downstream order are: Fort Peck Dam and Fort Peck Lake (MT), Garrison Dam and Lake Sakakawea (ND), Oahe Dam (SD) and Lake Oahe (ND and SD), Big Bend Dam and Lake Sharpe (SD), Fort Randall Dam and Lake Francis Case (SD), and Gavins Point Dam and Lewis and Clark Lake (NE and SD) (Figure 1-1). The six reservoirs impounded by the dams contain about 73.3 million acre-feet (MAF) of storage capacity and, at normal pool, an aggregate water surface area of about 1 million acres. Drought conditions in the upper Missouri River Basin in the early to mid-2000's reduced the water stored in the upper three Mainstem System reservoirs to record low levels. The water in storage at the all Mainstem System reservoirs at the end of 2010 (i.e., December 31, 2010) was 57.03 MAF, which is about 78 percent of the total Mainstem System storage volume. Table 5-1 gives selected engineering data for each of the six reservoirs

5.1.1 REGULATION OF THE MAINSTEM SYSTEM

The Mainstem System is a hydraulically and electrically integrated system that is regulated to obtain the optimum fulfillment of the multipurpose benefits for which the dams and reservoirs were authorized and constructed. The Congressionally authorized purposes of the Mainstem System are flood control, navigation, hydropower, water supply, water quality, irrigation, recreation, and fish and wildlife (including threatened and endangered species). The Mainstem System is operated under the guidelines described in the Missouri River Mainstem System Master Water Control Manual, (Master Manual) (USACE-RCC, 2006a). The Master Manual details regulation for all authorized purposes as well as emergency regulation procedures in accordance with the authorized purposes.

Mainstem System regulation is, in many ways, a repetitive annual cycle that begins in late winter with the onset of snowmelt. The annual melting of mountain and plains snow packs along with spring and summer rainfall produces the annual runoff into the Mainstem System. In a typical year, mountain snow pack, plains snow pack, and rainfall events respectively contribute 50, 25, and 25 percent of the annual runoff to the Mainstem System. After reaching a peak, usually during July, the amount of water stored in the Mainstem System declines until late in the winter when the cycle begins anew. A similar pattern may be found in rates of releases from the Mainstem System, with the higher levels of releases from mid-March to late-November, followed by low rates of winter discharge from late-November until mid-March, after which the cycle repeats.

To maximize the service to all of the authorized purposes, given the physical and authorization limitations of the Mainstem System, the total storage available in the Mainstem System is divided into four regulation zones that are applied to the individual reservoirs. These four regulation zones are: 1) Exclusive Flood Control Zone, 2) Annual Flood Control and Multiple Use Zone, 3) Carryover Multiple Use Zone, and 4) Permanent Pool Zone.

Table 5-1. Summary of selected engineering data for the Missouri River Mainstem System.

	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point
General						
Lake Name	Fort Peck Lake	Lake Sakakawea	Lake Oahe	Lake Sharpe	Lake Francis Case	Lewis and Clark Lake
River Mile (1960 Mileage)	1771.5	1389.9	1072.3	987.4	880.0	811.1
Total and Incremental Drainage Area (square miles)	57,500	181,400 123,900	243,490 62,900	249,330 5,840	263,480 145,150	279,480 16,000
Reservoir Length at Top of Carryover Multiple Use Pool (miles)	134	178	231	80	107	25
Shoreline Length at Top of Carryover Multiple Use Pool (miles)	1,520	1,340	2,250	200	540	90
Top Elevation of Carryover Multiple Use Pool (ft-NGVD29)	2234.0	1837.5	1607.5	1422.0	1350.0	1208.0
Year Storage First Available for Regulation of Flows	1940	1955	1962	1964	1953	1955
Original "As-Built" Conditions (Year)	(1937)	(1953)	(1958)	(1963)	(1953)	(1955)
Surface Area of Carryover Multiple Use Pool (acres)	214,718	322,030	314,649	59,150	82,000	31,100
Capacity of Carryover Multiple Use Pool (acre-feet)	15,869,000	18,917,000	19,490,000	1,920,000	3,911,000	510,000
Mean Depth at top of Carryover Multiple Use Pool[(1)] (feet)	73.9	58.7	61.9	32.5	47.7	16.4
Most Recent Surveyed Conditions (Year)	(2007)	(1988)	(1989)	(1997)	(1996)	(2007)
Surface Area at top of Carryover Multiple Use Pool (acres)	210,700	307,400	312,100	59,700	76,700	26,900
Capacity of Carryover Multiple Use Pool (acre-feet)	14,788,000	18,110,000	18,834,000	1,738,000	3,124,000	393,000
Mean Depth at top of Multiple Use Pool[(1)] (feet)	70.2	58.9	60.3	29.1	40.7	14.6
Sediment Deposition to Top of Carryover Multiple Use Pool						
Surveyed Sediment Deposition[(2)] (acre-feet)	1,081,000	807,000	656,000	182,000	787,000	117,000
Years of Sediment Deposition[(3)] (Survey Year - "As-Built Year")	70	35	31	34	43	52
Annual Sedimentation Rate[(4)] (acre-feet/year)	15,443	23,057	21,161	5,353	18,302	2,250
Annual Rate of Volume Loss from "As-Built" Condition	0.10%	0.12%	0.11%	0.28%	0.47%	0.44%
Years from "As-Built" to 2010	73	57	52	47	57	55
Estimated Sediment Deposition (acre-feet) through 2010[(5)]	1,127,329	1,314,257	1,100,387	251,588	1,043,233	123,750
2010 Estimated Capacity of Carryover Multiple Use Pool[(6)] (acre-feet)	14,741,671	17,602,743	18,389,613	1,668,412	2,867,767	386,250
Estimated Carryover Multiple Use Pool Capacity Lost through 2009	7.1%	6.9%	5.6%	13.1%	26. 7%	24.3%
Operational Details – Historic (1967 through 2010)						
Maximum Recorded Pool Elevation (ft-NGVD29)	2251.6	1854.8	1618.7	1422.1	1372.2	1209.7
Minimum Recorded Pool Elevation (ft-NGVD29)	2196.2	1805.8	1570.2	1414.9	1317.9	1199.8
Average Daily Pool Elevation (ft-NGVD29)	2229.4	1834.7	1601.4	1420.4	1351.1	1206.8
Maximum Recorded Daily Inflow (cfs)	160,000	180,000	204,000	79,000	100,000	74,000
Maximum Recorded Daily Outflow (cfs)	35,400	65,200	59,300	74,300	67,500	70,100
Average Annual Inflow (ac-ft)	7,237,000	16,195,000	17,925,000	16,981,000	17,931,000	19,674,000
Average Annual Outflow (ac-ft)	6,581,000	15,250,000	17,036,000	16,806,000	17,645,000	19,631,000
Operational Details – Current (2010)						
Maximum Recorded Pool Elevation (ft-NGVD29)	2235.9	1851.4	1617.9	1421.4	1368.1	1209.7
Minimum Recorded Pool Elevation (ft-NGVD29)	2221.1	1837.1	1604.7	1419.4	1337.3	1206.7
Maximum Recorded Daily Inflow (cfs)	36,000	85,000	65,000	50,000	73,000	59,000
Maximum Recorded Daily Outflow (cfs)	8,800	31,400	49,100	56,700	48,500	50,900
Total Inflow (% of Average Annual)	7,521,000 ac-ft (104%)	14,763,000 ac-ft (91%)	17,462,000 ac-ft (97%)	16,750,000 (99%)	19,546,000 (106%)	21,862,000 (111%)
Total Outflow (% of Average Annual)	4,072,000 ac-ft (62%)	13,185,000 ac-ft (86%)	17,209,000 ac-ft (101%)	16,564,000 (99%)	18,374,000 (104%)	23,921,000 (122%)
Power Tunnel Entrance Invert Elevation	2095 ft-NGVD29 (65 feet above bottom)	1672 ft-NGVD29 (2 feet above bottom)	1525 ft-NGVD29 (110 feet above bottom)	1330 ft-NGVD29 (Bottom)	1229 ft-NGVD29 (2 feet above bottom)	1139.5 ft-NGVD29 (Bottom)

Note: All elevations given are in the NGVD 29 datum.

(1) Mean Depth to top of Carryover Multiple Use Pool = Capacity of Carryover Multiple Use Pool (divided by) Surface Area of Carryover Multiple Use Pool.

(2) Surveyed Sediment Deposition is for the capacity (ac-ft) below the top of the Carryover Multipurpose Use Pool = "As-Built" capacity of Carryover Multiple Use Pool (minus) most recent surveyed capacity of Carryover Multiple Use Pool.

(3) Years of Sediment Deposition = year of most recent survey (minus) the "as-built" year.

(4) Annual Sedimentation Rate (ac-ft/yr) = Survey Sediment Deposition / Years of Sediment Deposition.

(5) Estimated Sediment Deposition through 2010 = Annual Sedimentation Rate (times) Years from "As-Built" to 2010.

(6) Current Capacity of Carryover Multiple Use Pool (ac-ft) = "As-Built" Capacity of Carryover Multiple Use Pool (minus) Current Estimated Capacity of Carryover Multiple Use Pool.

5.1.1.1 Exclusive Flood Control Zone

Flood control is the only authorized purpose that requires empty space in the reservoirs to achieve the objective. A top zone in each Mainstem System reservoir is reserved for use to meet the flood control requirements. This storage space is used only for detention of extreme or unpredictable flood flows and is evacuated as rapidly as downstream conditions permit, while still serving the overall flood control objective of protecting life and property. The Exclusive Flood Control Zone encompasses 4.7 MAF and represents the upper 6 percent of the total Mainstem System storage volume. This zone, from 73.3 MAF down to 68.7 MAF, is normally empty. The four largest reservoirs, Fort Peck, Garrison, Oahe, and Fort Randall, contain 97 percent of the total storage reserved for the Exclusive Flood Control Zone.

5.1.1.2 Annual Flood Control and Multiple Use Zone

An upper "normal operating zone" is reserved annually for the capture and retention of runoff (normal and flood) and for annual multiple-purpose regulation of this impounded water. The Mainstem System storage capacity in this zone is 11.7 MAF and represents 16 percent of the total Mainstem System storage. This storage zone, which extends from 68.7 MAF down to 57.0 MAF, will normally be evacuated to the base of this zone by March 1 to provide adequate storage capacity for capturing runoff during the next flood season. On an annual basis, water will be impounded in this zone as required to achieve the Mainstem System flood control purpose, and also be stored in the interest of general water conservation to serve all the other authorized purposes. The evacuation of water from the Annual Flood Control and Multiple Use Zone is scheduled to maximize service to the authorized purposes that depend on water from the Mainstem System. Scheduling releases from this zone is limited by the flood control objective in that the evacuation must be completed by the beginning of the next flood season. This is normally accomplished as long as the evacuation is possible without contributing to serious downstream flooding. Evacuation is, therefore, accomplished mainly during the summer and fall because Missouri River ice formation and the potential for flooding from higher release rates limit release rates during the December through March period.

5.1.1.3 Carryover Multiple Use Zone

The Carryover Multiple Use Zone is the largest storage zone extending from 57.0 MAF down to 18.0 MAF, and represents 53 percent of the total Mainstem System storage volume. Serving the authorized purposes during an extended drought is an important regulation objective of the Mainstem System. The Carryover Multiple Use Zone provides a storage reserve to support authorized purposes during drought conditions. Providing this storage is the primary reason the upper three reservoirs of the Mainstem System are so large compared to other Federal water resource projects. The Carryover Multiple Use Zone is often referred to as the "bank account" for water in the Mainstem System because of its role in supporting authorized purposes during critical dry periods when the storage in the Annual Flood Control and Multiple Use Zone is exhausted. Only the reservoirs at Fort Peck, Garrison, Oahe, and Fort Randall have this storage as a designated storage zone. The three larger reservoirs (Fort Peck, Garrison, and Oahe) provide water to the Mainstem System during drought periods to provide for authorized purposes. The storage space assigned to this zone in Fort Randall Reservoir serves a different purpose. It is normally evacuated each year during the fall season to provide recapture space for upstream winter power releases. The recapture results in complete refill of Fort Randall Reservoir during the winter months. During drought periods, the three smaller projects (Fort Randall, Big Bend, and Gavins Point) reservoir levels are maintained at the same elevation they would be at if runoff conditions were normal.

5.1.1.4 <u>Permanent Pool Zone</u>

The Permanent Pool Zone is the bottom zone that is intended to be permanently filled with water. The zone provides for future sediment storage capacity and maintenance of minimum pool levels for power heads, irrigation diversions, water supply, recreation, water quality, and fish and wildlife. A drawdown into this zone will generally not be scheduled except in unusual conditions. The Mainstem System storage capacity in this storage zone is 18.0 MAF and represents 25 percent of the total storage volume. The Permanent Pool Zone extends from 18.0 MAF down to 0 MAF.

5.1.2 WATER CONTROL PLAN FOR THE MAINSTEM SYSTEM

Variations in runoff into the Mainstem System necessitates varied regulation plans to accommodate the multipurpose regulation objectives. The two primary high-risk flood seasons are the plains snowmelt and rainfall season extending from late February through April, and the mountain snowmelt and rainfall period extending from May through July. Also, the winter ice-jam flood period, which extends from mid-December through February, can be a high-risk flood period. The highest average power generation period extends from mid-April to mid-October, with high peaking loads during the winter heating season (mid-December to mid-February) and the summer air conditioning season (mid-June to mid-August). The power needs during the winter are supplied primarily with Fort Peck and Garrison Dam releases and the peaking capacity of Oahe and Big Bend Dams. During the spring and summer period, releases are normally geared to navigation and flood control requirements, and primary power loads are supplied using the four lower dams. During the fall when power needs diminish, Fort Randall is normally drawn down to permit generation during the winter period when Oahe and Big Bend peaking-power releases refill the reservoir. The normal 8-month navigation season extends from April 1 through November 30, during which time Mainstem System releases are increased to meet downstream target flows in combination with downstream tributary inflows. Winter releases after the close of the navigation season are much lower and vary depending on the need to conserve or evacuate storage volumes, downstream ice conditions permitting. Releases and pool fluctuations for fish spawning management generally occur from April 1 through June. Two threatened and endangered bird species, piping plover (*Charadrius melodus*) and least tern (*Sterna antillarum*), nest on "sandbar" areas from early May through mid-August. Other factors may vary widely from year to year, such as the amount of water-in-storage and the magnitude and distribution of inflow received during the coming year. All these factors will affect the timing and magnitude of Mainstem System releases. The gain or loss in the water stored at each reservoir must also be considered in scheduling the amount of water transferred between reservoirs to achieve the desired storage levels and to generate power. These items are continually reviewed as they occur and are appraised with respect to the expected range of regulation.

5.1.3 OCCURRENCE OF "TWO-STORY" FISHERIES

Fort Peck, Garrison, and Oahe Reservoirs maintain "two-story" fisheries that are comprised of warmwater and coldwater species. The ability of the reservoirs to maintain "two-story" fisheries is due to their thermal stratification in the summer that allows coldwater habitat to be maintained in the hypolimnion. Warmwater species present in the reservoirs that are recreationally important include walleye (*Sander vitreus*), sauger (*Sander canadensis*), northern pike (*Esox lucius*), smallmouth bass (*Micropterus dolomieu*), catfish (*Ictalurus spp.*), and yellow perch (*Perca flavescens*). Coldwater species of recreational importance are the Chinook salmon (*Oncorhynchus tshawytscha*) and lake trout (*Salvelinus namaycush*). Chinook salmon are maintained in all three reservoirs through regular stocking, and a naturally-reproducing lake trout fishery is present in Fort Peck Reservoir. Other coldwater species present are rainbow smelt (*Osmerus mordax*) in Oahe and Garrison Reservoirs and lake cisco (*Coregonus artedi*) in Fort Peck Reservoir. Both these species are important forage fish that are utilized extensively by all recreational species in the respective reservoirs. Maintaining healthy populations of these coldwater forage fish is important to maintaining the recreational fisheries in the three reservoirs.

The occurrence of coldwater habitat in Fort Peck, Garrison, and Oahe Reservoirs is directly dependent on each reservoir's annual thermal regime. Early in the winter ice-cover period, the entire reservoir volume will be supportive of coldwater habitat. As the winter ice-cover period continues, lower dissolved oxygen concentrations will occur near the bottom as organic matter decomposes and reservoir mixing is prevented by ice cover. As dissolved oxygen concentrations in the near-bottom water fall below 5 mg/l, coldwater habitat will not be supported. During the spring isothermal period (spring turnover), water temperatures and dissolved oxygen levels in the entire reservoir volume will be supportive of coldwater habitat. During the early-summer warming period, the epilimnion will become non-supportive of coldwater habitat. During mid-summer when the reservoirs are experiencing maximum thermal stratification, water temperatures will only be supportive of coldwater habitat in the hypolimnion. Theoretically, coldwater habitat should remain stable during this period unless degradation of dissolved oxygen concentrations near the reservoir bottom becomes non-supportive of coldwater habitat. The most crucial period for the support of coldwater habitat in the three reservoirs is when they begin to cool in late summer. Coldwater habitat is reduced as convective cooling and wind-induced mixing of the epilimnion forces the thermocline deeper. As the thermocline moves deeper, the volume of the colder hypolimnion will continue to decrease while the expanding epilimnion may not yet be cold enough to be supportive of coldwater habitat. At the same time, dissolved oxygen levels in the hypolimnion are approaching their maximum degradation and dissolved oxygen concentrations below 5 mg/l are moving upward from the reservoir bottom; pinching off coldwater habitat from below. This situation will continue to worsen until the epilimnion cools enough to be supportive of coldwater habitat. When fall turnover occurs, dissolved oxygen concentrations at all depths will be near saturation and supportive of coldwater habitat. However, depending on the conditions of the reservoir, the isothermal temperature at the beginning of fall turnover may not be supportive of all coldwater habitats. This situation will continue to occur until the isothermal temperature cools to a suitable temperature, at which time the entire reservoir volume will be supportive of coldwater habitat.

5.2 FORT PECK

5.2.1 BACKGROUND INFORMATION

5.2.1.1 Project Overview

The Fort Peck Project was authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. Fort Peck Dam is located on the Missouri River at river mile (RM) 1771.5 in northeastern Montana, 17 miles southeast of Glasgow, MT. The closing of Fort Peck Dam in 1937 resulted in the formation of Fort Peck Reservoir (Fort Peck Lake). When full, the reservoir is 134 miles long, covers 246,000 acres, and has 1,520 miles of shoreline. Table 5-2 summarizes how the surface area, volume, mean depth, and retention time of Fort Peck Lake vary with pool elevations.

Over the period 1967 through 2010, the five generating units at Fort Peck Dam have produced an annual average 1.043 million MWh of electricity. Due to recent drought conditions, power production at the Fort Peck Dam generating units was reduced to an annual average of 0.633 million MWh over the 5-year period 2006 through 2010. Habitat for one endangered species, pallid sturgeon (*Scaphirhynchus albus*), occurs within the project area. The reservoir is used as a water supply by the town of Fort Peck, MT (RM1772 – penstock) and by individual cabins in the area. Fort Peck Lake is an important recreational resource and a major visitor destination in Montana.

Table 5-2. Surface area, volume, mean depth, and retention time of Fort Peck Lake at different pool elevations based on 2007 bathymetric survey.

Pool Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
2250	245,405	18,462,840	75.2	2.81
2245	237,605	17,253,500	72.6	2.62
2240	225,065	16,094,980	71.5	2.45
2235	213,025	15,000,180	70.4	2.28
2230	201,130	13,964,500	69.4	2.12
2225	188,765	12,991,390	68.8	1.97
2220	180,590	12,069,610	66.8	1.83
2215	171,930	11,188,080	65.1	1.70
2210	163,400	10,349,820	63.3	1.57
2205	154,773	9,554,578	61.7	1.45
2200	146,595	8,801,156	60.0	1.34
2195	138,081	8,090,417	58.6	1.23
2190	132,175	7,415,889	56.1	1.13
2185	126,146	6,769,319	53.7	1.03
2180	118,608	6,156,918	51.9	0.94
2175	111,285	5,582,093	50.2	0.85
2170	103,394	5,045,002	48.8	0.77
2165	95,316	4,549,151	47.7	0.69
2160	89,461	4,087,903	45.7	0.62

Average Annual Inflow (1967 through 2010) = 7.237 Million Acre-Feet
Average Annual Outflow: (1967 through 2010) = 6.581 Million Acre-Feet
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 2250-2246 ft-NGVD29), Annual Flood Control and Multiple Use Zone (elev. 2246-2234 ft-NGVD29), Carryover Multiple Use Zone (elev. 2234-2160 ft-NGVD29), and Permanent Pool Zone (elev. 2160-2030 ft-NGVD29). All elevations are in the NGVD 29 datum.

Drought conditions in the western United States during the first decade of the 21th century lead to an appreciable drawdown of Fort Peck Lake. An historic low pool elevation of 2196.2 ft-NGVD29 was recorded in March 2007. Drought conditions broke at the end of the decade with the occurrence of above normal precipitation, and Fort Peck Lake recovered to normal pool elevations in 2010. The recorded pool elevation at Fort Peck Lake at the end of December 2010 was 2235.4 ft-NGVD29; 1 foot into the Annual Flood Control and Multiple Use Zone. This is 14.3 feet higher than the reservoir was 1-year ago at the end of 2009, and 36.6 feet higher than the reservoir was 2-years ago at the end of 2008.

The major inflow to Fort Peck Lake is the Missouri River with minor inflows coming from the Musselshell River and Big Dry Creek. Water discharged through Fort Peck Dam for power production is withdrawn from Fort Peck Lake at elevation 2095 ft-NGVD29 – approximately 65 feet above the reservoir bottom. Figure 5-1 provides a schematic drawing of the outlet works at Fort Peck Dam.

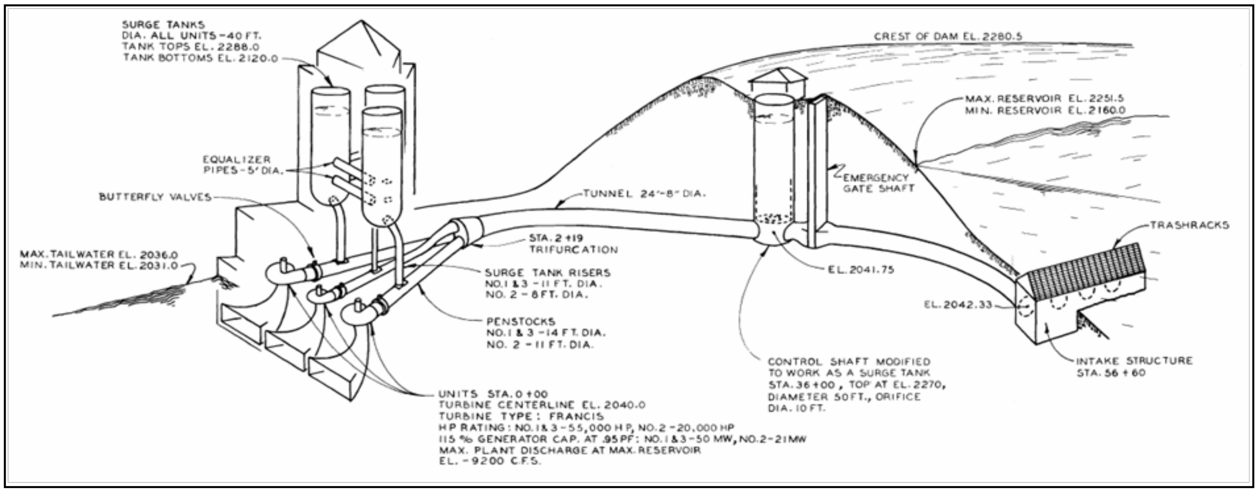


Figure 5-1. **S**chematic drawing of the outlet works at Fort Peck Dam.

5.2.1.2 <u>Water Quality Standards Classifications and Section 303(d) Listings</u>

5.2.1.2.1 Fort Peck Lake

The State of Montana has assigned Fort Peck Lake a B-3 classification in the State's water quality standards. As such, the reservoir is to be maintained suitable for drinking, culinary, and food processing purposes, after conventional treatment; bathing, swimming, and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply. Fort Peck Lake is not assigned a coldwater fishery use by the State in their water quality standards; however, the reservoir supports a stocked salmon fishery and a naturally reproducing lake trout and lake cisco fishery – all are considered coldwater species. Since a coldwater fishery is currently supported in Fort Peck Lake it is seemingly an existing use and must be protected pursuant to the Federal Clean Water Act and antidegradation policy provisions (40 CFR 131.3). Pursuant to Section 303(d) of the Federal CWA, Montana has placed Fort Peck Lake on the State's list of impaired waters citing impairment to the use of drinking water. The impairment of drinking water is attributed to the pollutants of lead and mercury. The identified sources of these pollutants are agriculture, abandoned mining, atmospheric deposition, and historic bottom deposits. The State of Montana has also issued a fish consumption advisory for Fort Peck Lake due to mercury concerns.

5.2.1.2.2 Missouri River Downstream of Fort Peck Dam

The Missouri River downstream of Fort Peck Dam has been designated a B-2 classification from the dam to the confluence of the Milk River, and a B-3 classification from the Milk River confluence to the Montana/North Dakota state line (Montana water quality standards). Both B-2 and B-3 waters are to be maintained suitable for drinking, culinary, and food processing purposes, after conventional treatment; bathing, swimming, and recreation; waterfowl and furbearers; and agricultural and industrial water supply. In addition, B-2 waters are to maintain growth and marginal propagation of salmonid fishes and associated aquatic life, and B-3 waters are to maintain growth and propagation of non-salmonid fishes and associated aquatic life. The river is used as a water supply by several towns along the reach. Pursuant to Section 303(d) of the Federal Clean Water Act, Montana has placed the Missouri River downstream of Fort Peck Dam on the State's list of impaired waters citing impairment to the uses of aquatic life support, coldwater fishery, and warmwater fishery due to the stressors of water temperature, flow-regime

alterations, and degraded riparian vegetation. No fish consumption advisory has been issued for the Missouri River downstream of Fort Peck Dam by the State of Montana.

The Assiniboine and Sioux Tribes of the Fort Peck Indian Reservation have developed water quality standards, approved by the U.S. Environmental Protection Agency, that are applicable to their tribal lands. This includes an area on the north side of the Missouri River downstream of Fort Peck Dam from the Milk River to Big Muddy Creek. The tribal water quality standards applicable to this reach of the Missouri River are comparable to the State of Montana's water quality standards.

5.2.1.3 Water Quality for the Enhancement of Pallid Sturgeon Populations in the Missouri River Downstream of Fort Peck Dam

One of the few remaining populations of pallid sturgeon occurs in the Missouri River between Fort Peck Dam and the headwaters of Lake Sakakawea. Individuals in this population also inhabit the lower Yellowstone River. As such, this reach of the Missouri River has been identified as a priority recovery area for the pallid sturgeon (USFWS, 1993). It is believed that the building and operation of Fort Peck Dam and Reservoir have adversely impacted the pallid sturgeon in this reach of the Missouri River by regulating flows, lowering water temperatures, reducing sediment and nutrient transport, and increasing water clarity (USFWS, 2003).

Historically, the lower Missouri River in Montana was a turbid, warmwater environment with seasonally fluctuating flows. The sediment and turbidity of the water through these cycles contributed significantly to the evolution of the pallid sturgeon. The fish adapted to highly turbid and low visibility environments by physiologically evolving to enhance their ability to capture prey and avoid capture as juveniles and larvae in this low visibility environment. It is also believed that the pallid sturgeon adapted by developing spawning cues based on historical conditions in the river. The fish requires a spawning cue of suitable magnitude, duration, and timing to complete this life cycle element. It is believed that increasing flow and water temperature in the late spring is a primary factor for pallid sturgeon to initiate spawning.

Water temperature is believed to be a controlling factor on the pallid sturgeon in this reach of the Missouri River in regards to spawning cues and larval survival during the summer. Because Fort Peck Dam has a deepwater withdrawal from the reservoir, water temperature in the Missouri River downstream of the dam are appreciably colder than "pre-dam" conditions. A water temperature of around 18°C (64.4°F) is believed necessary to initiate a spawning response in pallid sturgeon. Colder water temperatures can affect larval pallid sturgeon survival and development, and likely adversely affects the production and availability of suitable forage (i.e., plankton and other invertebrate species) for the juvenile pallid sturgeon throughout the summer. With this in mind, a late-spring/early-summer water temperature of 18°C in the Missouri River at Frazer Rapids (approximately 25 miles downstream of Fort Peck Dam) has been identified as critical for pallid sturgeon spawning and recruitment in this reach of the river.

Fort Peck Dam and Reservoir is trapping sediment that historically moved down the Missouri River. It is also believed that the current colder water temperatures in the river downstream of the dam are likely suppressing production of plankton and other invertebrate organisms that contribute to turbidity of the water. The resulting clearer water is believed to adversely affect young pallid sturgeon by making them more vulnerable to sight-feeding predators and increasing competition for food by sight-adapted predators. In addition, adult fish may be adversely affected by the increased ability of prey to avoid capture in clearer water.

5.2.1.4 Ambient Water Quality Monitoring

The District has monitored water quality conditions at the Fort Peck Project since the late 1970's. Water quality monitoring locations have included sites on Fort Peck Lake and on the inflow to and outflow from the reservoir. A 3-year intensive water quality survey was completed at the Fort Peck Project in 2006, and the findings of the intensive survey are available in the separate report, "Water Quality Conditions Monitored at the Corps' Fort Peck Project in Montana during the 3-Year period 2004 through 2006" (USACE, 2007a). Other recent water quality reports concerning the Fort Peck Project include: "Simulation of Fort Peck Lake Temperature Releases and Downstream Missouri River Temperatures" (USACE, 2007b), "Fort Peck Temperature Control Device Reconnaissance Study Fort Peck, Montana" (Tetra Tech, 2009), and "Application of the CE-QUAL-W2 Hydrodynamic and Water Quality Model to Fort Peck Reservoir, Montana (USACE, 2009a). Figure 5-2 shows the location of sites at the Fort Peck Project that have been regularly monitored by the District for water quality during the 5-year period 2006 through 2010. The near-dam location (i.e., site FTPLK1772A) has been continuously monitored since 1980.

5.2.2 WATER QUALITY IN FORT PECK LAKE

5.2.2.1 Existing Water Quality Conditions

5.2.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Water quality conditions that were monitored in Fort Peck Lake at sites FTPLK1772A, FTPLK1805DW, and FTPLKBDCA02 from May through September during the 5-year period 2006 through 2010 are summarized, respectively, in Plate 1, Plate 2, and Plate 3. A review of these results found no significant water quality concerns. On a few occasions measured dissolved oxygen concentrations were below the water quality standards criterion of 5 mg/l for the protection of Class B-3 warmwater aquatic life in the mid-reaches of the Missouri River Arm. The measured low dissolved oxygen concentrations occurred in the hypolimnion near the reservoir bottom during the later part of the summer thermal stratification period. The lowest dissolved oxygen concentration measured was 3.7 mg/l and occurred at site FTPLK1805DW on August 23, 2007.

5.2.2.1.2 Summer Thermal Stratification

5.2.2.1.2.1 Monthly Longitudinal Temperature Contour Plots

Summer thermal stratification of Fort Peck Lake during 2010 is described by longitudinal temperature contour plots based on depth-profile temperature measurements taken during May, June, July, August, and September (Plate 4, Plate 5, Plate 6, Plate 7, and Plate 8). The contour plots were constructed along two longitudinal axes; the Missouri River mainstem arm and the Big Dry Creek arm. As seen in the contour plots, temperatures in Fort Peck Lake vary longitudinally from the dam to the Missouri River inflow and vertically from the reservoir surface to the bottom. The near-surface water in the upstream reach of the reservoir warms up sooner in the spring than the near-surface water near the dam. By mid-summer a strong thermocline becomes established in the downstream reach of the reservoir, and the near-surface waters of the entire reservoir above the thermocline are a fairly uniform temperature. As the near-surface waters of the reservoir cool in the late summer, the thermocline moves deeper, and the wind-mixed upper waters are fairly uniform in temperature. The vertical variation in temperature is most prevalent in the deeper area of the reservoir towards the dam, where a strong thermocline becomes established during the summer. The shallower upper reaches of Fort Peck Lake do not exhibit much vertical variation of temperature during mid- to late summer, as wind action allows for complete mixing of the water column.

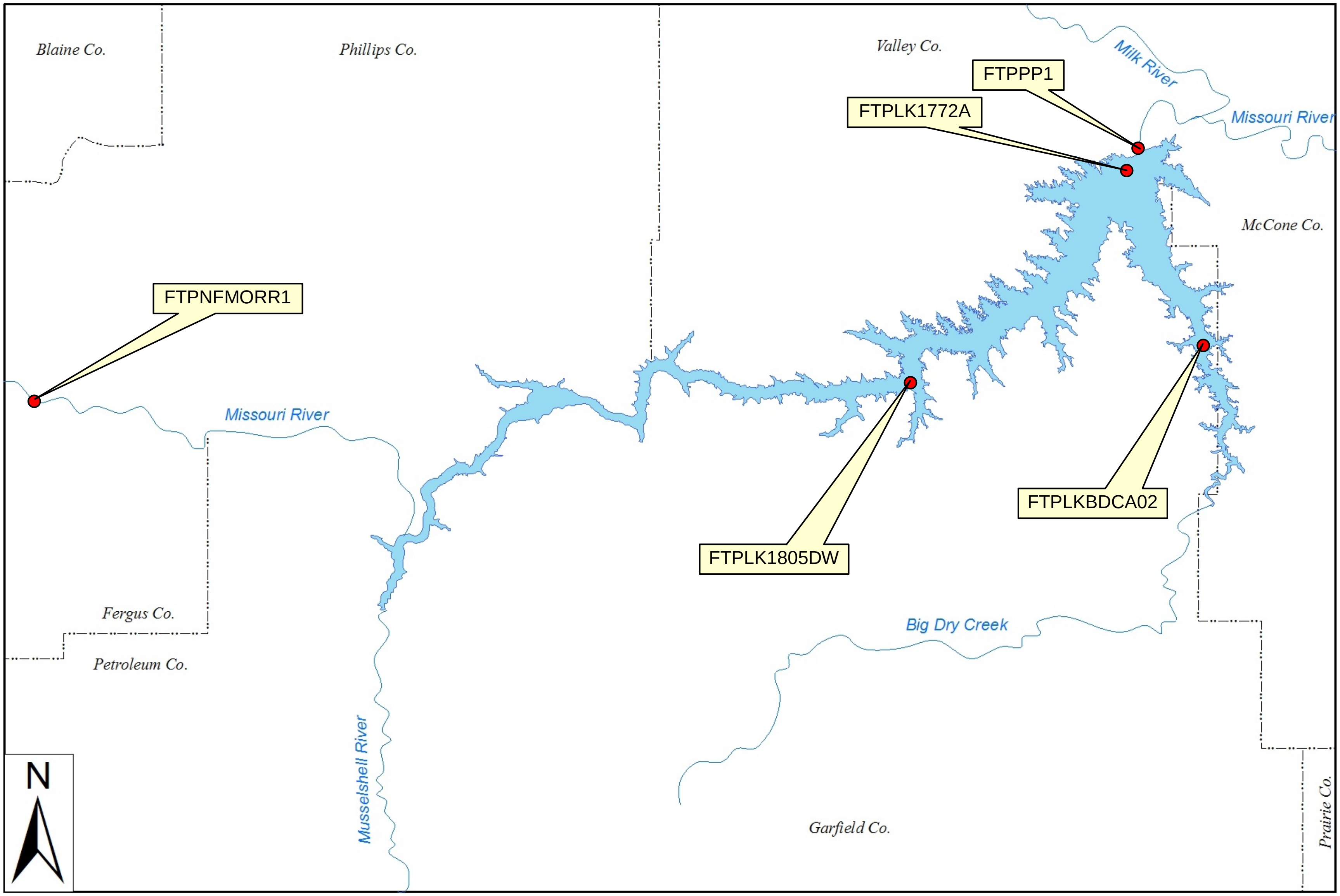


Figure 5-2. Location of sites where water quality monitoring was regularly conducted by the District at the Fort Peck Project during the 5-year period 2006 through 2010.

5.2.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Fort Peck Lake at the deep water area near the dam is described by the depth-profile temperature plots measured over the past 5 years. Depth-profile temperature plots measured during the summer were compiled (Plate 9). The plotted depth-profile measurements indicate that a significant temperature-depth gradient occurs in Fort Peck Lake in the near-dam lacustrine area during the summer, and a thermocline becomes established at a depth of about 20 meters.

5.2.2.1.3 Summer Dissolved Oxygen Conditions

5.2.2.1.3.1 Monthly Longitudinal Dissolved Oxygen Contour Plots

Summer dissolved oxygen conditions in Fort Peck Lake during 2010 are described by the monthly longitudinal dissolved oxygen contour plots based on depth-profile temperature measurements taken in May, June, July, August, and September (Plate 10, Plate 11, Plate 12, Plate 13, and Plate 14). The contour plots were constructed along two longitudinal axes; the Missouri River mainstem arm and the Big Dry Creek Arm. As shown in the contour plots, dissolved oxygen conditions in Fort Peck Lake vary longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Dissolved oxygen levels below 5 mg/l first appeared near the reservoir bottom in the middle reaches of the Missouri River Arm in September. Near-bottom dissolved oxygen concentrations near the dam remained above 5 mg/l. The earlier occurrence of low dissolved oxygen concentrations in the near-bottom water of the middle reaches of Fort Peck Lake is attributed to the increased organic loading in the transition zone of the reservoir and the lesser hypolimnetic volume available for assimilation of the oxygen demand. As this material decomposes, a "pool" of water with lower dissolved oxygen levels accumulates near the bottom in this area of the reservoir. Decomposition of autochthonous organic matter also occurs in the lacustrine zone and results in dissolved oxygen degradation as the summer progresses, although at a slower rate than what occurs in the transition zone. The recovery of near-bottom dissolved oxygen concentrations to saturation levels takes longer in the lacustrine zone nearer the dam because of the time needed for thermal stratification to breakdown and mixing within the water column to occur in the deeper water.

5.2.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Dissolved oxygen depth-profiles measured in the near-dam, deep-water region of Fort Peck Lake were plotted (Plate 15). The plotted depth-profiles were measured during the summer over the 5-year period 2006 through 2010. As shown in the plots, dissolved oxygen levels did not exhibit a large gradient with depth and tended toward an orthograde to slight clinograde vertical distribution. No dissolved oxygen concentrations below 5 mg/l were measured anywhere in the water column at anytime during the 5-year period.

5.2.2.1.4 Water Clarity

5.2.2.1.4.1 Secchi Transparency

Figure 5-3 displays a box plot of the Secchi depth transparencies measured at monitoring sites FTPLK1772A, FTPLK1805DW, and FTPLKBDCA02 during the 5-year period 2006 through 2010. Secchi depth transparency was observably lower in the upper reaches of both arms of the reservoir (i.e., sites FTPLK1805DW and FTPLKBDCA02) as compared to the near-dam conditions (i.e., site FTPLK1772A).

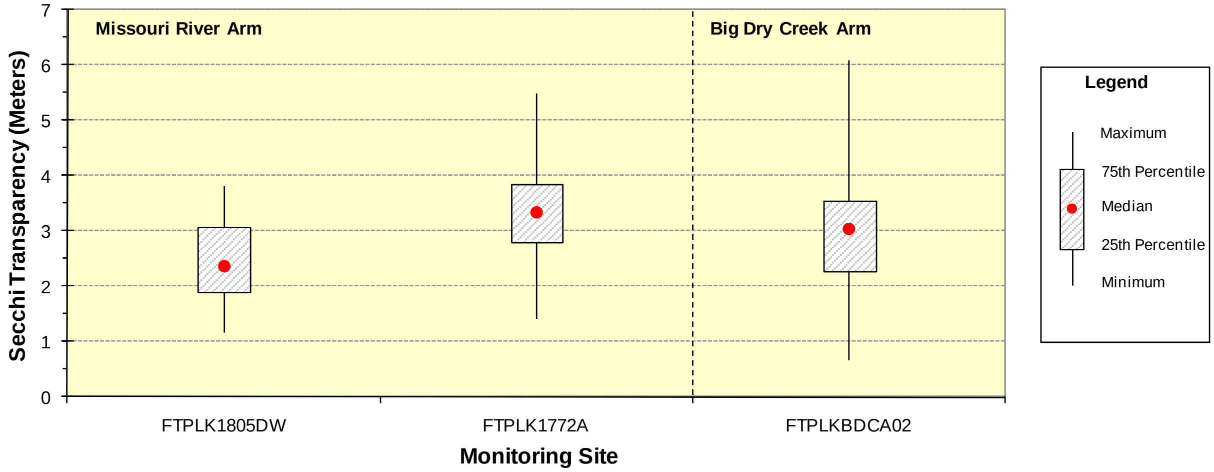


Figure 5-3. Box plot of Secchi transparencies measured in Fort Peck Lake during the 5-year period 2006 through 2010.

5.2.2.1.4.2 Turbidity

Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction or flux level. Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. Given the low chlorophyll *a* concentrations monitored in Fort Peck Lake, turbidity in the reservoir appears to be largely due to suspended inorganic material. Monthly (i.e., May, June, July, August, and September) longitudinal contour plots were prepared from the depth-profile turbidity measurements taken at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and, FTPNFMORR1 during 2010 (Plate 16, Plate 17, Plate 18, Plate 19, and Plate 20). As seen in the longitudinal contour plots, turbidity levels in Fort Peck Lake vary longitudinally from the dam to reservoir's upstream reaches. Turbidity levels are noticeably higher in the upstream reaches of the Missouri River Arm of the reservoir as compared to the area near the dam. This is attributed to the turbid conditions of the inflowing Missouri River.

5.2.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Fort Peck Lake during the summer were compared. Near-surface conditions were represented by samples collected within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 1-meter of the reservoir bottom. The compared samples were collected at the near-dam site FTPLK1772A during the 5-year period 2006 through 2010. During the period a total of 19 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Plate 21). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for all the assessed parameters except TOC, TKN, total ammonia, and total phosphorus. Parameters that were significantly lower in the near-bottom water of Fort Peck Lake included: water temperature ($p < 0.001$), dissolved oxygen ($p < 0.01$), and pH ($p < 0.001$). Parameters that were significantly higher in the near-bottom water included: ORP ($p < 0.001$) and alkalinity ($p < 0.05$).

5.2.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Fort Peck Lake were calculated from monitoring data collected during the 5-year period 2006 through 2010 (Table 5-3). The calculated TSI values indicate that the regions of the reservoir represented by the monitored sites are in a mesotrophic state.

Table 5-3. Mean Trophic State Index (TSI) values calculated for three sites on Fort Peck Lake based on monitoring conducted during the 5-year period 2006 through 2010.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
FTPLK1772A	44	52	48	48
FTPLK1805DW	48	49	53	50
FTPLKBDCA02	45	46	49	46

Note: See Section 4.1.4 for discussion of TSI calculation.

5.2.2.1.7 Plankton Community

5.2.2.1.7.1 Phytoplankton

Phytoplankton grab samples were collected from Fort Peck Lake at sites FTPLK1772A, FTPLK1805DW, and FTPLKBDCA02 during the spring and summer of the 5-year period 2006 through 2010 (Plate 22, Plate 23, and Plate 24). Taxa identified in the collected phytoplankton samples were from seven taxonomic divisions: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The relative abundance of phytoplankton, based on biovolume, in samples collected from Fort Peck Lake in May, July, and September 2010 is shown in Figure 5-4. Diatoms (Bacillariophyta) are by far the most dominant phytoplankton group present in Fort Peck Lake. Major phytoplankton genera sampled in Fort Peck Lake during 2010 (i.e., genera comprising more than 10% of the total biovolume of at least one sample) included the Bacillariophyta *Asterionella*, *Aulacoseria*, *Fragilaria, and Stephanodiscus*; Chrysophyta *Dinobryon*, and Cryptophyta *Rhodomonas*. No concentrations of the cyanobacteria toxin microcystin above 1 ug/l were monitored in the lake during the 5-year period 2006 through 2010 (Plate 1, Plate 2, and Plate 3).

5.2.2.1.7.2 Zooplankton

Zooplankton vertical-tow samples were collected from Fort Peck Lake at sites FTPLK1772A, FTPLK1805DW, and FTPLKBDCA02 in May, July, and September of 2010 (Plate 25). The sampled zooplankton included three taxonomic groupings: Cladocerans, Copepods, and Rotifers. The relative abundance of these three taxonomic grouping in the zooplankton samples collected in 2010 is shown in Figure 5-5. Cladocerans and copepods dominated the zooplankton community in Fort Peck Lake. Major zooplankton species sampled in Fort Peck Lake during 2010 (i.e., species comprising more than 10% of the total biomass of at least one sample) included Cladocerans *Bosmina longirostris, Daphnia galeata*, *Daphnia pulex*, and *Daphnia retrocurva*; Copepods *Cyclopoid copepodid, Diacyclops thomasi*, *Leptodiaptomus siciloides,* and *Mesocyclops edax*; and Rotifers *Keratella quadrata*. Dominant species (i.e., species comprising more than 25% of the total biomass of at least one sample) included Cladocerans *Daphnia retrocurva* and Copepods *Cyclopoid copepodid* and *Diacyclops thomasi*.

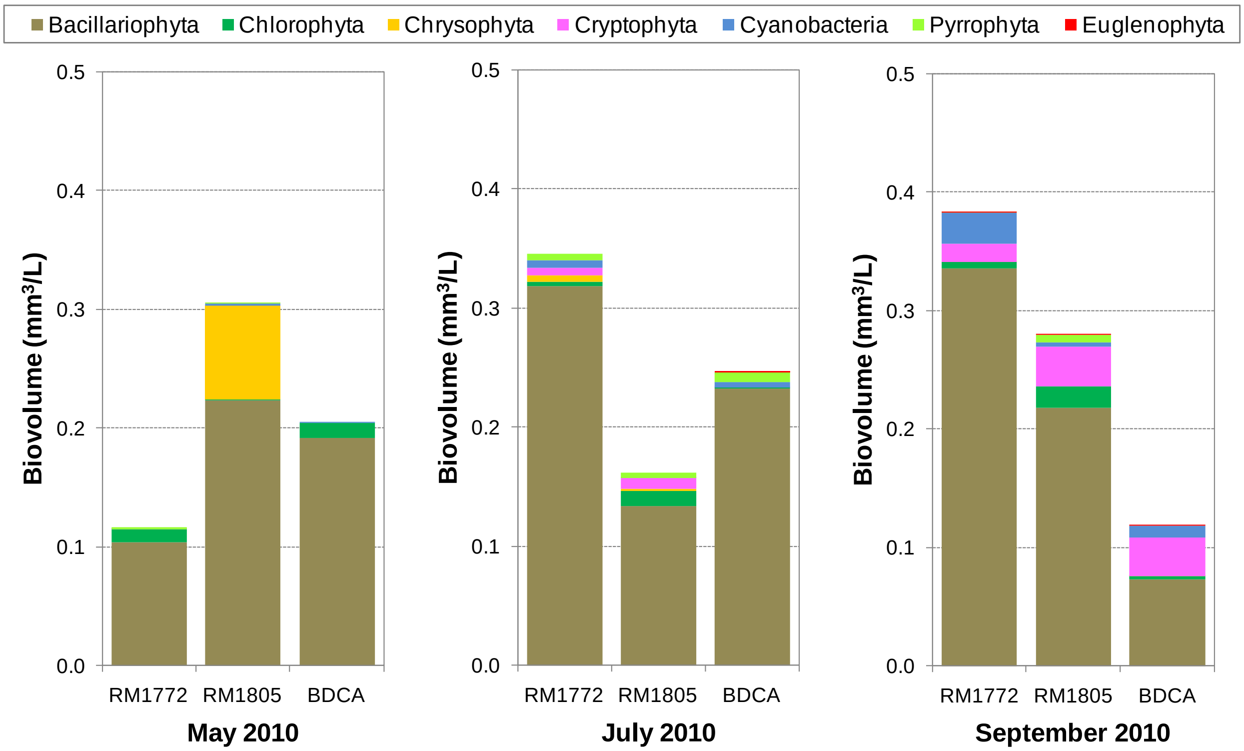


Figure 5-4. Relative abundance of phytoplankton in samples collected from Fort Peck Lake during 2010.

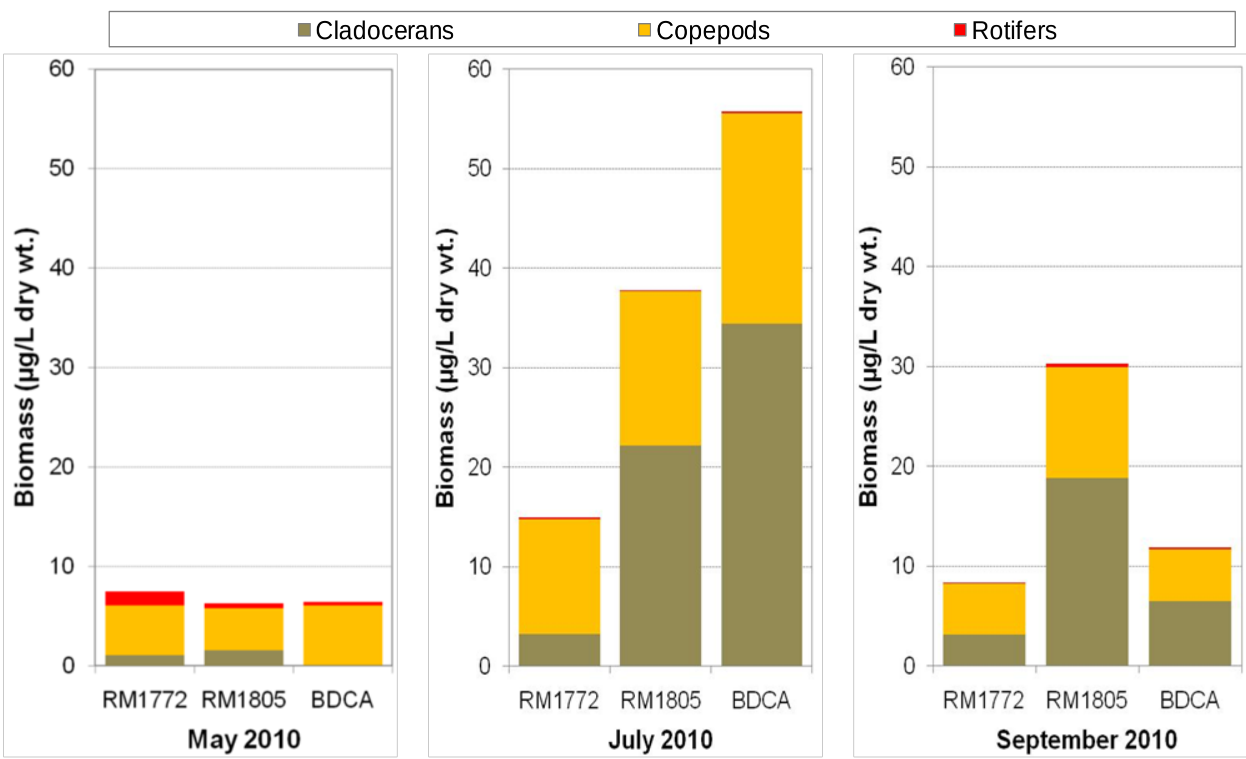


Figure 5-5. Relative abundance of zooplankton in samples collected from Fort Peck Lake during 2010.

5.2.2.1.8 Impairment of Designated Water Quality Beneficial Uses

Based on the State of Montana's impairment assessment methodology (Section 4.1.6.1), the water quality conditions monitored in Fort Peck Lake during the 5-year period 2006 through 2010 did not indicate any impairment of designated water quality beneficial uses. It is noted that the State of Montana has identified Fort Peck Lake as impaired (drinking water supply) due to lead and mercury (Table 1-3).

5.2.2.2 Water Quality Trends (1980 through 2009)

Water quality trends over the 31-year period of 1980 to 2010 were determined for Fort Peck Lake for Secchi depth, total phosphorus, chlorophyll a, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through September at the near-dam, ambient monitoring site (i.e., site FTPLK1772A). Plate 26 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, Fort Peck Lake exhibited significant trends for Secchi depth (decreasing), chlorophyll *a* (increasing), and TSI (increasing). No significant trend was detected for total phosphorus. Over the 31-year period, the reservoir has generally remained in a mesotrophic state.

5.2.3 EXISTING WATER QUALITY CONDITIONS OF THE MISSOURI RIVER INFLOW TO FORT PECK LAKE

5.2.3.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions that were monitored in the Missouri River near Landusky, MT (i.e., site FTPNFMORR1) April through September during the 5-year period 2006 through 2010 are summarized in Plate 27 and Plate 28. A review of these results indicated no major water quality concerns. It is noted that the human health standard for arsenic was exceeded for all four of the samples collected. The human health standard for arsenic is derived from the maximum contaminant level from Montana's drinking water regulations and uses a bioconcentration factor of 44. Very high levels of total iron and manganese were monitored. Seven of the nine total iron samples exceeded the chronic criterion for aquatic life protection. All of the total iron and 44 percent of the total manganese samples exceeded the secondary maximum contaminant level for aesthetics. The high levels of iron and manganese are believed to be a natural condition associated with the geology and soils of the region.

5.2.3.2 Vertical Water Quality Variation in the Missouri River

Depth discrete water quality monitoring of the Missouri River at site FTPNFMORR1 was initiated in 2010. Depth-profiles in ½-meter increments were measured for water temperature, dissolved oxygen, pH, conductivity, ORP, turbidity, and chlorophyll *a*. Near-surface and near-bottom grab samples were collected from the thalweg of the river at site FTPNFMORR1. The near-surface sample was collected by dipping a plastic churn bucket just below the water surface. The near-bottom sample was collected by lowering a finned-Van Dorn sampler to within ½-meter of the river bottom while the boat was drifting in the current.

5.2.3.2.1 Depth-Profile Plots

Depth-profile plots were constructed for water temperature, dissolved oxygen, pH, conductivity, turbidity, and chlorophyll *a* (Plate 29). The depth-profile plots indicate minimal variation in the six parameters with depth. The plots do indicate appreciable differences for selected parameters between monitoring dates.

5.2.3.2.2 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected at site FTPNFMORR1 during 2010 were compared. Four paired samples (May, June, July, and August) were collected during 2010. Box plots were constructed to display the distribution of the paired near-surface and near-bottom samples for selected non-particulate-associated (i.e., water temperature, total dissolved solid, dissolved sulfate, and dissolved phosphorus) and particulate-associated (i.e., total suspended solids, total suspended sediment, total Kjeldahl nitrogen, total phosphorus, and total organic carbon) constituents (Plate 30). Anecdotally, the box plots indicate no significant depth variation in the non-particulate- associated constituents. The box plots of the particulate-associated constituents indicate the maximum values for all these constituents were associated with the bottom samples. Box plots for total suspended sediment and total organic carbon indicate a higher distribution for the bottom samples. A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were not found to be significantly different for any parameter. It is noted that the small sample size limited the power of the applied statistical method to test for significant differences, and more testing will be done in the future as additional samples are collected.

The near-surface and near-bottom concentrations of the particulate-associated constituents total phosphorus, total Kjeldahl nitrogen, total suspended sediment, total suspended solids, and total organic carbon measured at site FTPNFMORR1 were plotted against the flow of the Missouri River at the time of sampling (Plate 31). Near-bottom concentrations of the particulate-associated constituents were higher than the near-surface levels during low and moderate flow. However, at the highest flow the near-surface and near-bottom concentrations were similar. The near-surface levels of total suspended solids and total organic carbon were noticeably higher than the near-bottom concentrations at the highest flow level (i.e., 25,300 cfs). Seemingly, the higher flow may have enhanced vertical mixing in the river.

5.2.3.3 <u>Missouri River Inflow Nutrient Flux Conditions</u>

Nutrient flux rates for the Missouri River inflow to Fort Peck Lake over the 5-year period 2006 through 2010 were calculated based on near-surface water quality samples collected near Landusky, MT (i.e. site FTPNFMORR1) and the instantaneous flow conditions at the time of sample collection (Table 5-4). It must be recognized that the concentrations of particulate-associated constituents can vary from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) are likely higher nearer the river bottom, near-surface grab samples likely under estimate the “true” water-column composite concentration for these constituents. Thus, the flux rates given for total phosphorus and total organic carbon in Table 5-4 should be considered minimum estimates with the actual flux rates likely being higher. The maximum flux rates for all the constituents are believed to be attributed to higher nonpoint-source loadings during runoff conditions.

Table 5-4. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Landusky, MT (i.e., site FTPNFMORR1) during April through September over the 5-year period 2006 through 2010.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)(1)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)(1)
No. of Obs.	27	27	27	27	27	27	26
Mean	9,090	0.0109	0.2560	0.0124	0.1056	0.0070	0.8073
Median	7,830	n.d.	0.1472	n.d.	0.0199	n.d.	0.6697
Minimum	3,978	n.d.	n.d.	n.d.	0.0034	n.d.	0.1675
Maximum	25,300	0.1032	1.3243	0.1079	1.0549	0.0454	2.8656

Note: Nondetectable values set to 0 for flux calculations.
(1) Flux calculations for total phosphorus and total organic carbon are biased estimates based on sampled near-surface concentrations (see text for further discussion).

5.2.3.4 Continuous Water Temperature Monitoring of the Missouri River at USGS Gage Site 06115200 near Landusky, Montana

Through an agreement with the U.S. Geological Survey (USGS), a water temperature monitoring probe was added to the USGS's gage (06115200) on the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1). Beginning in October 2004, hourly water temperature measurements were recorded at the site. Plate 32, Plate 33, Plate 34, Plate 35, and Plate 36, respectively, plot mean daily water temperature and river discharge for the years 2006, 2007, 2008, 2009, and 2010. No water temperature data were collected in 2007 (the temperature monitoring probe became inoperable, and USGS was unable to repair it during 2007).

5.2.4 WATER QUALITY AT THE FORT PECK POWERPLANT

5.2.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 37 and Plate 38 summarize the water quality conditions that were monitored from water discharged through Fort Peck Dam during the 5-year period of 2006 through 2010. A review of these results indicated only one possible water quality concern regarding dissolved oxygen. The 1-day dissolved oxygen minimum criterion of 8.0 mg/l for the protection of coldwater B-2 early life stages was not met for 11 percent of the dissolved oxygen measurements. The 8.0 mg/l criterion is a water column concentration recommended to achieve an in-gravel dissolved oxygen concentrations of 5.0 mg/l. For species that have early life stages exposed directly to the water column, the criterion is 5.0 mg/l. No dissolved oxygen measurements were below 5.0 mg/l. The B-2 classification of the Missouri River downstream of Fort Peck Dam only extends to the confluence of the Milk River, a distance of approximately 10 miles. Given the coldwater species and recruitment present, the 5.0 mg/l water column dissolved criterion may be appropriate for this reach. Also, the dissolved oxygen measurements below 8.0 mg/l tended to occur in later summer when the effects on early life stages are likely to be reduced. Therefore, the observed dissolved oxygen measurements below 8.0 mg/l are not believed to be a significant water quality concern at this time.

5.2.4.2 Impairment of Designated Water Quality Beneficial Uses

Based on the State of Montana's impairment assessment methodology (Section 4.1.6.1), the water quality conditions monitored at the Fort Peck powerplant during the 5-year period 2006 through 2010 did not indicate any impairment of designated water quality beneficial uses. It is noted that the State of Montana has identified the Missouri River downstream of Fort Peck Dam as impaired (cold and warm water fisheries) due to water temperature (Table 1-3).

5.2.4.3 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Semiannual time-series plots for temperature, dissolved oxygen, and dam discharge monitored at the Fort Peck powerplant during the 5-year period of 2006 through 2010 are shown in Plate 39 through Plate 58. Water temperatures showed seasonal warming and cooling through each calendar year. Dissolved oxygen levels remained relatively high and stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall. The lowest dissolved oxygen levels occurred during the late summer/early fall period. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. The decreasing dissolved oxygen in the July to September period is attributed to ongoing degradation of dissolved oxygen in the lower hypolimnion of Fort Peck Lake as the summer progressed. Water is withdrawn from the reservoir into the dam's power tunnels approximately 65 feet above the reservoir bottom. There appeared to be little correlation between discharge rates and measured water temperature and dissolved oxygen concentrations.

5.2.4.4 Comparison of Monitored Inflow and Outflow Temperatures of the Missouri River at Fort Peck Lake

Plate 59 through Plate 62, respectively, plot the mean daily water temperatures monitored at the Missouri River near Landusky, MT (site FTPNFMORR1) and the Fort Peck Dam powerplant (site FTPPP1) for 2006, 2008, 2009, and 2010. Inflow temperatures of the Missouri River to Fort Peck Lake are generally warmer than the outflow temperatures of Fort Peck Dam during the period of March through August. Outflow temperatures of the Fort Peck Dam discharge are generally warmer than the inflow temperatures of the Missouri River during the period of September through February. A maximum temperature difference occurs in the summer when the Missouri River inflow temperature is about 10° to 12°C warmer than the Fort Peck Dam outflow temperature. A plot for 2007 comparing water temperatures of the Missouri River inflow and outflow to Fort Peck Lake was not possible because water temperatures were not recorded at the USGS gage near Landusky, MT (06115200) in 2007 due to equipment problems.

5.2.4.5 Nutrient Flux Conditions of the Fort Peck Dam Discharge to the Missouri River

Nutrient flux rates for the Fort Peck Dam discharge to the Missouri River over the 5-year period 2006 through 2010 were calculated based on samples taken from the Fort Peck powerplant (i.e. site FTPPP1) and the dam discharge at the time of sample collection (Table 5-5). During this 5-year period, all water discharged at Fort Peck Dam was through the powerplant. The samples collected in the powerplant are taken from the raw water supply line and are believed to be unbiased regarding particulate-associated constituents. Therefore, the flux rates calculated for the Fort Peck Dam discharge give an unbiased estimate of the flux rates for all the constituents, including total phosphorus and total organic carbon. The maximum flux rates for all the constituents are believed to be attributed to higher dam discharges.

5.2.5 WATER QUALITY IN THE MISSOURI RIVER DOWNSTREAM FROM FORT PECK DAM

Water temperatures have been monitored in the Missouri River downstream of Fort Peck Dam over the past several years as part of a multi-agency effort to study the pallid sturgeon population in the Missouri and Yellowstone Rivers. Three sites on the Missouri River that have been monitored by the USGS under this effort are the Fort Peck Dam tailwaters (RM1765), Nickels Rapids (RM1757.5), and Frazer Rapids (RM1748).

Table 5-5. Summary of nutrient flux rates (kg/sec) calculated for the Fort Peck Dam discharge to the Missouri River (i.e., site FTPPP1) during January through December over the 5-year period 2006 through 2010.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	48	48	48	48	48	46	47
Mean	6,401	0.0058	0.0693	0.0030	0.0042	0.0016	0.5025
Median	6,080	n.d.	0.0448	n.d.	0.0034	n.d.	0.4386
Minimum	3,423	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	12,513	0.0739	0.3897	0.0265	0.0217	0.0071	1.5155

Note: Nondetectable values set to 0 for flux calculations.

The water temperatures monitored at the Fort Peck Dam powerplant during the period 2006 through 2010 were plotted with the Missouri River water temperatures monitored by the USGS. Plate 63, Plate 64, Plate 65, Plate 66, and Plate 67, respectively, plot mean daily water temperatures monitored at the sites and the mean daily discharge of Fort Peck Dam from May through October during 2006, 2007, 2008, 2009, and 2010. During the 5 years, water temperatures monitored at the Fort Peck Dam powerplant from June through August were generally 1°C to 2°C cooler than the water temperatures monitored in the Missouri River at the Fort Peck Dam tailwaters site, and 3°C to 5°C cooler than the water temperatures monitored in the Missouri River at Nickels and Frazer Rapids. During early to mid-September of each year, water temperatures monitored at the three sites were somewhat similar. In early September the water temperatures monitored at the Fort Peck Dam powerplant exhibited warming. This is attributed to the cooling and downward expansion of the epilimnion in Fort Peck Lake as "fall turnover" of the reservoir approached. It appears that in early September the downward expanding epilimnion intersected with the upper reaches of "withdrawal zone" of the intake for the power tunnels. This resulted in warmer epilimnetic warmer being captured in the reservoir and discharged through Fort Peck Dam. During late-September to early October, water temperatures monitored at the Fort Peck powerplant were generally warmer than those monitored in the Missouri River downstream of Fort Peck Dam. This is attributed to the slower heat loss from Fort Peck Lake than the Missouri River in early fall. Warmer water from the epilimnion of Fort Peck Lake is discharged through Fort Peck Dam that cools as it moves down the Missouri River. It is during this time period that the relationship of warmer water temperatures occurring in the Missouri River at Frazer Rapids and cooler water temperatures occurring at the Fort Peck Dam powerplant reverses.

5.3 GARRISON

5.3.1 BACKGROUND INFORMATION

5.3.1.1 <u>Project Overview</u>

Garrison Dam is located in central North Dakota on the Missouri River at RM 1389.9, about 75 miles northwest of Bismarck, ND and 11 miles south of the town of Garrison, ND. Construction of the project began in 1946, and closure of Garrison Dam in 1953 resulted in the formation of Garrison Reservoir (Lake Sakakawea), which is the largest Corps reservoir in the United States. When full, the reservoir is 178 miles long, up to 6 miles wide, and has 1,884 miles of shoreline. The reservoir contains almost a third of the total storage capacity of the Mainstem System, nearly 24 million acre-ft. Table 5-6 summarizes how the surface area, volume, mean depth, and retention time of Lake Sakakawea vary with pool elevations. The reservoir has recovered from recent drought conditions and was at pool elevation of

1841.70 ft-NGVD29 at the end of December 2010. At a pool elevation of 1841.7 ft-NGVD29, Lake Sakakawea is 4.2 feet above the top of the Carryover Multiple Use Zone (1837.5 ft-NGVD29). Major inflows to the reservoir are the Missouri and Yellowstone Rivers, and a minor inflow is the Little Missouri River. Water discharged through Garrison Dam for power production is withdrawn from Lake Sakakawea at elevation 1672.0 ft-NGVD29, approximately 2 feet above the reservoir bottom. Figure 5-6 shows a schematic drawing of the outlet works at Garrison Dam.

Garrison was authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. Over the period 1967 through 2010, the five generating units at Garrison Dam have produced an annual average 2.245 million MWh of electricity. The recent drought in the western United States has curtailed releases and power production at the Mainstem System projects, including Garrison. Power production at the Garrison Dam generating units averaged an annual 1.536 million MWh over the 5-year period 2006 through 2010. Habitat for two endangered species, pallid sturgeon and interior least tern, and one threatened species, piping plover, occurs within the project area. The reservoir is used as a water supply by some individual cabins and by the towns of Williston (RM1553), Four Bears (RM1481), Mandaree (RM1467), Twin Buttes (RM1432), White Shield (RM1415), Parshall (RM1451), Garrison (RM1395), Riverdale (RM1390 – Garrison Dam), and Pick City (RM1390 – Garrison Dam), ND. The Shared Southwest Pipeline Project intake is at RM1414 (Dickinson, ND). Lake Sakakawea is an important recreational resource and a major visitor destination in North Dakota.

Table 5-6. Surface area, volume, mean depth, and retention time of Lake Sakakawea at different pool elevations based on 1988 bathymetric survey.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1855	384,480	24,203,180	63.0	1.59
1850	364,265	22,331,620	61.3	1.46
1845	344,460	20,558,360	59.7	1.35
1840	320,600	18,893,560	58.9	1.24
1835	296,210	17,355,220	58.6	1.14
1830	280,520	15,916,490	56.7	1.04
1825	263,525	14,556,980	55.2	0.95
1820	249,665	13,275,410	53.2	0.87
1815	235,600	12,061,430	51.2	0.79
1810	219,955	10,921,980	49.7	0.72
1805	204,453	9,861,138	48.2	0.65
1800	188,998	8,877,219	47.0	0.58
1795	173,070	7,973,682	46.1	0.52
1790	161,295	7,139,184	44.3	0.47
1785	148,759	6,364,791	42.8	0.42
1780	138,809	5,646,736	40.7	0.37
1775	128,261	4,979,890	38.8	0.33

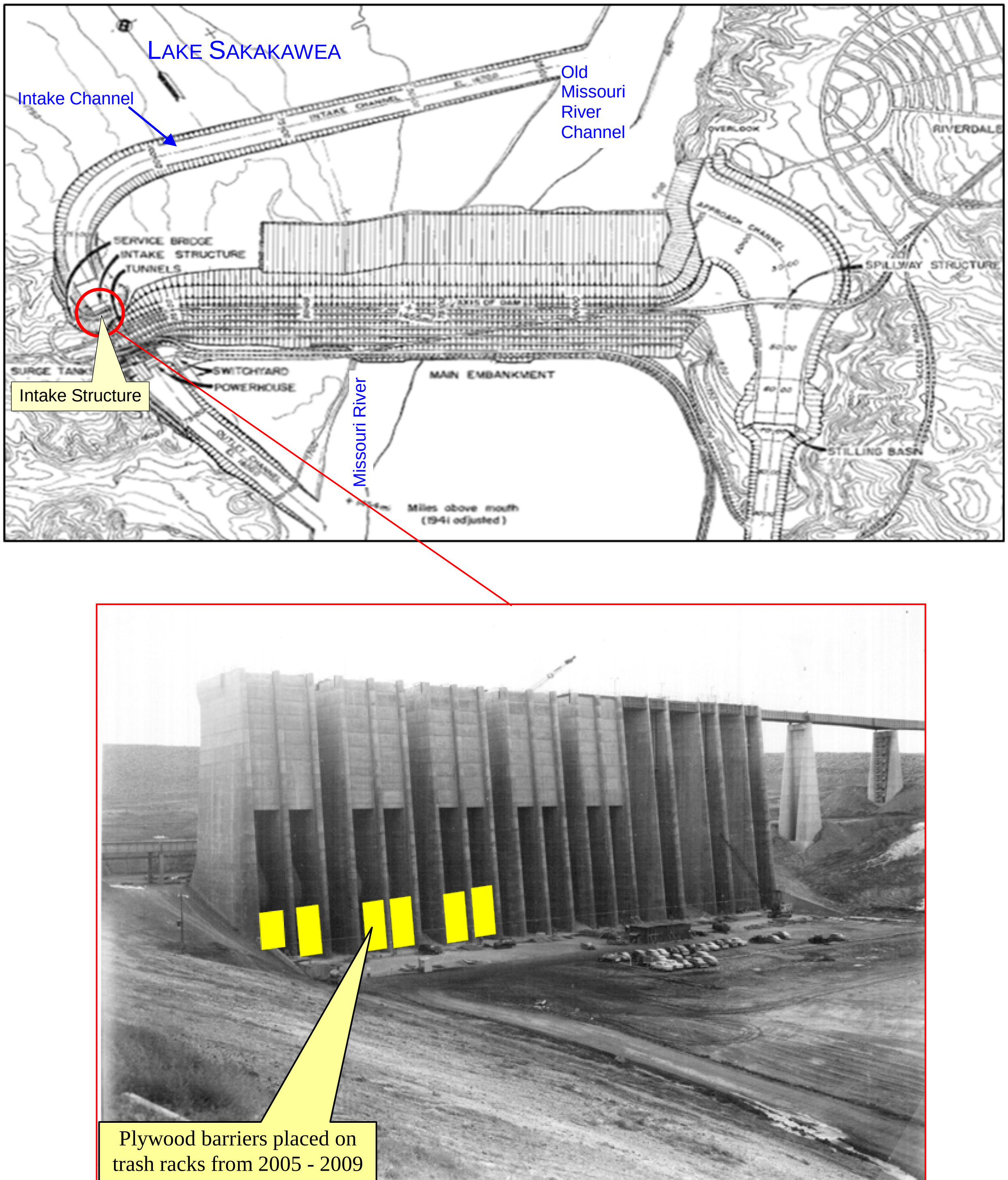
Average Annual Inflow (1967 through 2010) = 16.20 Million Acre-Feet

Average Annual Outflow: (1967 through 2010) = 15.25 Million Acre-Feet

* Mean Depth = Volume ÷ Surface Area.

** Retention Time = Volume ÷ Average Annual Outflow.

Note: Exclusive Flood Control Zone (elev. 1854-1850 ft-NGVD29), Annual Flood Control and Multiple Use Zone (elev. 1850-1837.5 ft-NGVD29), Carryover Multiple Use Zone (elev. 1837.5-1775 ft-NGVD29), and Permanent Pool Zone (elev. 1775-1670 ft-NGVD29). All elevations are in the NGVD 29 datum.



Garrison Dam Intake Structure During Construction (10-Dec-1952)

Figure 5-6. Schematic drawing of Garrison Dam and channel to intake structure and photo of intake structure during construction.
Note: Plywood barriers installed for water quality management (see Section 5.3.1.3.2.1).

5.3.1.2 Water Quality Standards Classifications and Section 303(d) Listings

5.3.1.2.1 Lake Sakakawea

The State of North Dakota has classified Lake Sakakawea as a Class 1 lake. As such, the reservoir is to be protected for a coldwater fishery; swimming, boating, and other water recreation; irrigation; stock watering; wildlife; and municipal or domestic use after appropriate treatment. Pursuant to Section 303(d) of the Federal Clean Water Act, North Dakota has placed the Lake Sakakawea on the State's list of impaired waters citing impairment to the use fish consumption. The impairment to fish consumption is attributed to methyl-mercury contamination of fish tissue. The State of North Dakota has issued a fish consumption advisory for Lake Sakakawea due to mercury concerns.

5.3.1.2.2 Missouri River Downstream of Garrison Dam

The State of North Dakota has classified the entire Missouri River as a Class 1 stream. As such, the river is to be suitable for the propagation and/or protection of resident fish species and other aquatic biota; swimming, boating, and other water recreation; irrigation; stock watering; wildlife; and municipal or domestic use after appropriate treatment. The river has not been placed on the State's Section 303(d) list of impaired waters. The State of North Dakota has issued a fish consumption advisory for the Missouri River due to mercury concerns.

5.3.1.3 Management of Coldwater Habitat in Lake Sakakawea

5.3.1.3.1 Coldwater Habitat Criteria – Water Temperature and Dissolved Oxygen

North Dakota defines Class 1 lakes, including Lake Sakakawea, as waters capable of supporting growth of coldwater fish species (e.g., salmonids) and associated biota. Water temperature and dissolved oxygen levels are primary water quality factors that determine the suitability of water for coldwater aquatic life. The State of North Dakota has promulgated a hypolimnetic maximum temperature criterion of 15°C for Class 1 lakes and reservoirs that are thermally stratified. The State also adopted a water quality standard that states that Lake Sakakawea must maintain a minimum volume of water of 500,000 acre-feet that has a temperature of 15°C or less and a dissolved oxygen concentration of not less than 5 mg/l.

5.3.1.3.2 Implementation of Short-term Water Quality Management Measures to Preserve Coldwater Habitat in Lake Sakakawea

The most crucial period for the support of coldwater habitat in Lake Sakakawea is when it begins to cool in late summer. As the thermocline moves deeper, the volume of the coldwater hypolimnion continues to decrease while the expanding epilimnion has not cooled enough to be supportive of coldwater habitat. At the same time, hypolimnetic dissolved oxygen concentrations are approaching their maximum degradation and low dissolved oxygen levels are moving upward from the reservoir bottom and "pinching off" coldwater habitat from below. This situation continues to worsen until the epilimnion cools enough to be supportive of coldwater habitat and the reservoir eventually experiences fall turnover. The volume of the hypolimnion (i.e., coldwater habitat) occurring in Lake Sakakawea during the summer decreases with lower pool levels.

As drought conditions persisted in early 2005, water levels in Lake Sakakawea had fallen to a record low pool elevation of 1805.8 feet-msl on May 12, 2005. At that time it was felt that unless water quality management measures were implemented in 2005 to preserve the coldwater habitat in the reservoir, the recreational sport fishery would likely be adversely impacted. The reduction of coldwater

habitat is exacerbated by withdrawals through the Garrison Dam intake structure. Because the invert elevation of the intake portals to the Garrison Dam power tunnels (i.e., penstocks) is 2 feet above the reservoir bottom, water drawn through the penstocks comes largely from the lower depths of the reservoir. Thus, during the summer thermal-stratification period, water is largely drawn from the hypolimnetic volume of Lake Sakakawea. Three short-term water quality management measures were identified for implementation in 2005 in an effort to preserve the coldwater habitat in the reservoir. These measures, which were implemented at Garrison Dam, included: 1) application of a plywood barrier to the dam's intake trash racks, 2) utilization of head gates to restrict the opening to the dam's power tunnels, and 3) modification of the daily flow cycle and minimum flow releases from the dam. The three implemented water quality management measures were targeted at drawing water into the dam from higher elevations within Lake Sakakawea.

5.3.1.3.2.1 Application of a Plywood Barrier to the Dam's Intake Trash Racks

The five power tunnels at Garrison Dam are screened at the upstream end of the water passage by trash racks. These trash racks prevent large objects from entering the penstocks and causing serious damage to the wicket gates and turbine. Each of the five Units has two intake passages for a total of ten intakes. The trash rack for each of the ten intakes consists of seven separate frame sections. The trash rack fits into the trash rack slots at the front of the intake passage piers. A hook for each rack is fixed to the top of the frame. A lifting beam and mobile crane is used to raise and lower each trash rack.

The existing trash racks were modified to raise the elevation where water was withdrawn from Lake Sakakawea. The trash rack modification consisted of installing plywood sheathing on the upstream side of the existing trash rack grates on the passages to Units 1, 2 and 3 (Figure 5-6). The plywood sheathing was applied to Units 2 and 3 in July 2005 and covered the lower 48 feet of the trash racks (i.e., approximately elevation 1672 to 1720 ft-NGVD29) with the exception of a 3-inch slot at the very bottom for passing sediments. In mid-May 2007, attempts were made to install plywood barriers to the trash racks of Unit 1. Due to a large tree at the bottom of the east intake to Unit 1, plywood could not be installed on all the trash racks. The bottom trash rack on the east side of Unit 1 could not be removed and did not receive a plywood barrier. There are 2½ trash racks with plywood barriers on the east side of Unit 1 and 3½ trash racks with plywood on the west side. Therefore, a plywood barrier existed on the west side of Unit 1 from elevation 1672 to 1720 ft-NGVD29, and on the east side of Unit 1 from elevation 1688 to 1720 ft-NGVD29. With the recovery of pool elevations in Lake Sakakawea in 2009, the plywood barriers were removed from the trash racks of all three Units in mid-October 2009.

5.3.1.3.2.2 Utilization of Head Gates to Restrict the Opening to the Dam's Power Tunnels

Each of the intake passages to all five power tunnels have operational head gates that control flow into the penstocks. It was reasoned that lowering one of the two head gates to block a single passage to the power tunnel should increase the velocity of water drawn into the power tunnel, given the total flow through the power tunnel remained the same. Increasing the velocity of the water drawn into the intake could pull water from a higher elevation in Lake Sakakawea and possibly help maintain the reservoir's deeper, coldwater volume. To implement this measure in 2006, single head gates on the passages to Units 1 and 4 were lowered on July 5, 2006. Similarly in 2007, single head gates on the passages to Units 1 and 4 were lowered on May 30, 2007 and were raised on October 2, 2007. The head gates were not lowered in 2008 or 2009.

5.3.1.3.2.3 Modification of Daily Flow Cycle and Maximum and Minimum Flow Releases

Past water quality monitoring at the Garrison Dam powerhouse indicated that the vertical extent of the withdrawal zone in Lake Sakakawea during summer thermal stratification was dependent on the

discharge rate of the dam. Warmer water high in dissolved oxygen was drawn down from higher elevations in the reservoir under higher discharge rates, and colder water low in dissolved oxygen was drawn from the lower depths of the reservoir under lower discharge rates. The influence of the dam's discharge rate on the reservoir withdrawal zone is believed to be partly attributed to the design of the intake structure and submerged intake channel.

To the extent possible, flow releases from Garrison Dam during 2005 through 2008 were modified to try to maximize the water drawn from higher elevations and minimize the water drawn from lower elevations in Lake Sakakawea. The following two flow release modifications were pursued: 1) daily flow releases should be in either a maximum or minimum mode; and 2) minimum flows should be discharged through Units 2 and 3, which have the "full" plywood barriers in place. Unit 1, with a "partial" plywood barrier, should be used as a back-up to Units 2 and 3 for discharging minimum flows.

5.3.1.3.3 Performance Assessment Report

A more detailed discussion of the implementation of the short-term water quality management measures and their effects through 2005 is given in the Performance Assessment Report, "Garrison Cold Water Fishery Performance Assessment" (USACE, 2006b).

5.3.1.4 Ambient Water Quality Monitoring

The District has monitored water quality conditions at the Garrison Project since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow to and outflow from the reservoir. A 3-year intensive water quality survey was completed at the Garrison Project in 2005 and the findings of the intensive survey are available in the separate report, "Water Quality Conditions Monitored at the Corps' Garrison Project in North Dakota during the 3-Year period 2003 through 2005" (USACE, 2006c). Figure 5-7 shows the location of sites at the Garrison Project that were monitored by the District for water quality during the 5-year period 2006 through 2010. The near-dam location (i.e., site GARLK1390A) has been continuously monitored since 1980.

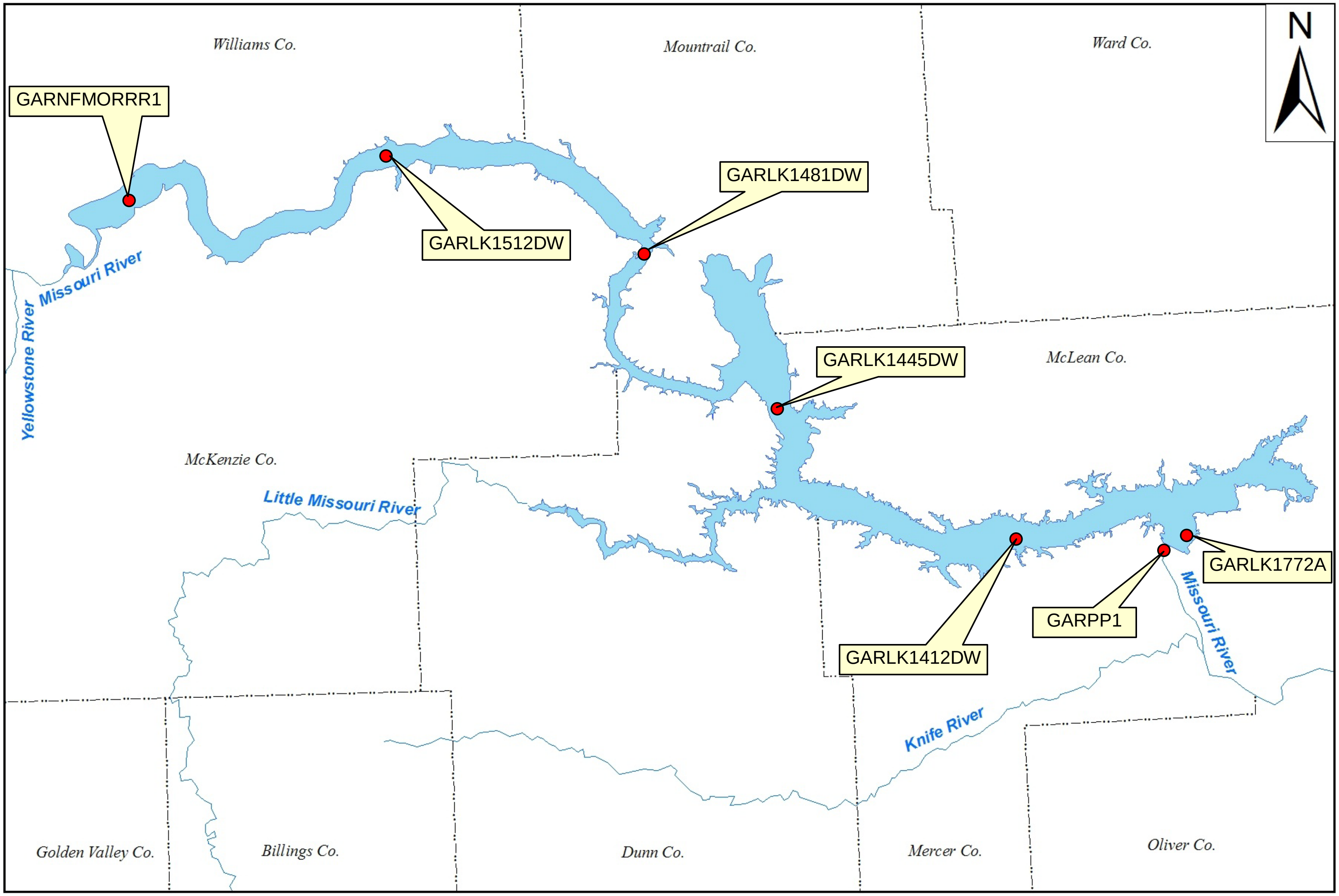


Figure 5-7. Location of sites where water quality monitoring was conducted by the District at the Garrison Project during the 5-year period 2006 through 2010.

5.3.2 WATER QUALITY IN LAKE SAKAKAWEA

5.3.2.1 <u>Existing Water Quality Conditions</u>

5.3.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Water quality conditions that were monitored in Lake Sakakawea at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARLK1512DW from May through September during the 5-year period 2006 through 2010 are summarized in Plate 68, Plate 69, Plate 70, Plate 71, and Plate 72. A review of these results indicated possible water quality concerns regarding water temperature and dissolved oxygen for the support of coldwater fishery habitat in the hypolimnion of Lake Sakakawea. For assessment purposes, the bottom of the metalimnion is generally defined as the depth where a temperature drop of at least 1.0°C last occurs over a 1-meter depth increment, and the top of the hypolimnion is generally defined as the depth where a temperature drop of at least 0.5°C last occurs over a 1-meter depth increment. Monitored water quality conditions in the hypolimnion of Lake Sakakawea regularly exceeded the 15°C and 5 mg/l criteria for temperature and dissolved oxygen. However, it is noted that the frequency of exceedance decreased in 2009 and 2010 with the return to higher pool levels. Dissolved oxygen levels in the hypolimnion continually degrade along the reservoir bottom as summer progresses. Dissolved oxygen levels fall below 5 mg/l in the upstream reaches of the hypolimnion first and progress towards the dam. Also, as the summer progresses, low dissolved oxygen conditions move up from the reservoir bottom into the mid and upper reaches of the hypolimnion. This pinching off of coldwater habitat threatens the support of the coldwater fishery in the reservoir, especially under low pool levels during drought conditions. The assessment of coldwater fishery habitat in Lake Sakakawea is further discussed in Section 5.3.2.1.4. The lowest dissolved oxygen concentration measured in Lake Sakakawea over the 5-year period was 1.0 mg/l and occurred near the reservoir bottom at site GARLK1445DW in August 2006.

5.3.2.1.2 Summer Thermal Stratification

5.3.2.1.2.1 Monthly Longitudinal Temperature Contour Plots

Late-spring and summer thermal stratification of Lake Sakakawea during 2010 is described by longitudinal temperature contour plots along the length of the reservoir (Plate 73, Plate 74, Plate 75, Plate 76, and Plate 77). The contour plots are based on depth-profile temperature measurements taken monthly from May through September along the submerged Missouri River channel. As seen in the contour plots, water temperature in Lake Sakakawea varies longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. The near-surface water in the upstream reaches of the reservoir warms up sooner in the spring than the near-surface water near the dam. By mid-summer a strong thermocline becomes established in the downstream reaches of the reservoir, and the near-surface waters of the entire reservoir above the thermocline are a fairly uniform temperature. As the near-surface waters of the reservoir cool in the late summer, the thermocline is pushed deeper and the wind-mixed upper waters are isothermal. The vertical variation in temperature is most prevalent in the deeper area of the reservoir towards the dam where a strong thermocline becomes established during the summer. The shallower upstream reaches of Lake Sakakawea do not exhibit much vertical variation of temperature during mid to late summer as wind action allows for the water column to completely mix.

5.3.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Lake Sakakawea at the deep water area near the dam is described by the depth-profile temperature plots measured over the past 5 years. Depth-profile temperature plots measured during the summer were compiled (Plate 78). The plotted depth-profile measurements indicate that a significant temperature-depth gradient occurs in Lake Sakakawea in the near-dam lacustrine area during the summer, and a thermocline becomes established at a depth of about 25 meters.

5.3.2.1.3 Summer Dissolved Oxygen Conditions

5.3.2.1.3.1 Monthly Longitudinal Dissolved Oxygen Contour Plots

Dissolved oxygen contour plots were constructed along the length of Lake Sakakawea based on depth-profile measurements taken in May, June, July, August, and September of 2010 (Plate 79, Plate 80, Plate 81, Plate 82, and Plate 83). During the summer of 2010, dissolved oxygen conditions in Lake Sakakawea varied longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Dissolved oxygen levels below 5 mg/l first appeared near the reservoir bottom in the middle reaches of the reservoir in August. In September, dissolved oxygen concentrations recovered in the middle reaches or the reservoir, and lower dissolved oxygen levels occurred along the reservoir bottom in the area near the dam. The earlier occurrence of low dissolved oxygen concentrations in the near-bottom water of the middle reaches of Lake Sakakawea is attributed to the increased allochthonous organic loading in the transition zone of the reservoir and the lesser hypolimnetic volume available for assimilation of the oxygen demand. As this material decomposes, a "pool" of water with low dissolved oxygen levels accumulates near the bottom in this area of the reservoir. Decomposition of autochthonous organic matter also occurs in the lacustrine zone and results in dissolved oxygen degradation as the summer progresses, although at a slower rate than what occurs in the transition zone. The recovery of near-bottom dissolved oxygen concentrations to saturation levels takes longer in the lacustrine zone nearer the dam because of the longer time needed for thermal stratification to breakdown and mixing within the water column to occur in the deeper water. The near-bottom outlet at the dam likely results in an interflow along the reservoir bottom that promotes the movement of oxygen-demanding material and low dissolved oxygen water from the middle reaches of the reservoir to the dam. Any interflow affect would likely increase as pool elevations drop and the reservoir's retention time decreases.

5.3.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Existing summer dissolved oxygen conditions in Lake Sakakawea at the deep water area near the dam are described by the depth-profile dissolved oxygen plots. Depth-profile dissolved oxygen plots measured during the summer over the 5-year period 2006 through 2010 were compiled (Plate 84). Dissolved oxygen levels exhibited a significant gradient with depth and tended toward a clinograde vertical distribution. During the 5-year period 2006 through 2010, dissolved oxygen concentrations in the lower hypolimnion fell below 5 mg/l in September of 2006, 2007, and 2008. The lowest dissolved oxygen concentration measured at this site was 3.8 mg/l in 2006. No dissolved oxygen concentration below 5 mg/l was monitored at the near-dam site in 2009 and 2010. This is attributed to the higher pool levels in these 2 years which resulted in a greater hypolimnetic volume that provided a greater assimilative capacity for oxygen demand.

5.3.2.1.4 Occurrence of Coldwater Fishery Habitat in Lake Sakakawea

The occurrence of coldwater habitat (i.e., water temperature ≤ 15°C and dissolved oxygen ≥ 5 mg/l) in Lake Sakakawea was estimated from collected water temperature and dissolved oxygen depth-profile measurements and defined reservoir elevation and volume relationships. Plate 85 displays a plot of pool elevations and the coldwater fishery habitat estimated to have been present in Lake Sakakawea during the summers of 2003 through 2010. As previously mentioned, the State of North Dakota recently promulgated a water quality standard that states that Lake Sakakawea must maintain a minimum volume of water of 500,000 acre-feet that has a temperature of 15°C or less and a dissolved oxygen concentration of not less than 5 mg/l. Plate 86 displays the same information shown in Plate 85 except the y-axis is scaled to a maximum value of 4-million acre-feet. This allows the estimated coldwater habitat volumes near the 500,000 acre-feet water quality standard to be better discerned. During the 8-year period 2003

through 2010, the 500,000 ac-ft water quality standard was seemingly not met in Lake Sakakawea in late-summer (i.e., September) during the 6-year period 2003 through 2008. The 500,000 ac-ft water quality standard was seemingly met in 2009 and 2010. This indicates that the 500,000 ac-ft water quality standard is seemingly not met during periods of low pool levels as occurred during the drought period of 2003 through 2008.

The 500,000 ac-ft water quality standard of temperature ≤15°C and dissolved oxygen ≥ 5 mg/l for the hypolimnion of Lake Sakakawea was seemingly met in 2009 and 2010 (Plate 85 and Plate 86). As indicated in Plate 85 and Plate 86, significantly more coldwater habitat was estimated to be present in 2009 and 2010 versus 2003 through 2008. This is largely attributed to the higher pool elevations and resulting larger hypolimnetic volume that occurred at Lake Sakakawea throughout 2009 and 2010.

The occurrence of coldwater habitat in Lake Sakakawea is believed to be highly dependent on pool elevation. Since coldwater habitat only occurs in the hypolimnion of the reservoir during the summer, the size of the hypolimnion will directly determine the amount of coldwater habitat potentially available. The upper extent of the hypolimnion is delineated by the thermocline (i.e., zone of rapid temperature decline) which separates the colder hypolimnion from the warmer, less dense water of the epilimnion. Depending on climatic factors, the thermocline in an individual reservoir will generally be established at a similar depth from year to year. Therefore, a greater hypolimnetic volume will tend to occur under higher pool elevations and a lesser hypolimnetic volume will tend to occur under lower pool elevations. The pool elevation in late-spring and early summer when the thermocline first becomes established is especially important as later changes in pool elevations are mitigated somewhat by the stratification already established. A larger hypolimnetic volume also has a greater assimilative capacity for oxygen demanding materials which can degrade dissolved oxygen levels in the hypolimnion below the coldwater habitat standard of 5 mg/l.

The relationship between the occurrence of coldwater habitat and pool elevation is generally seen in the coldwater habitat estimated to have occurred in Lake Sakakawea during 2003 through 2010 (Plate 85 and Plate 86). The years with the highest pool elevations (i.e., 2010, 2009, and 2003) generally had the highest estimated occurrence of coldwater habitat. The years with the lower pool elevations (i.e., 2005, 2006, and 2007) generally had the lowest estimated occurrence of coldwater habitat. It is noted that 2004 was an atypical year of cloudy, cooler weather that resulted in cooler lake temperatures. Atypical pool elevations occurred in 2008. In 2008, pool elevations rose from the lowest level to near the highest levels recorded during the 6-year period 2003 through 2008 (Plate 85). The seemingly lower occurrence of coldwater habitat estimated in 2008 may be a result of the lower pool levels that occurred in late-spring when the hypolimnion was becoming established.

5.3.2.1.5 Water Clarity

5.3.2.1.5.1 Secchi Transparency

Figure 5-8 displays a box plot of the Secchi depth transparencies measured along Lake Sakakawea at the five sites GARLK1512DW, GARLK1481DW, GARLK1445DW, GARLK1412DW, and GARLK1390A during 2010. Secchi depth transparency significantly increased in a downstream direction between sites GARLK1512DW, GARLK1481DW, GARLK1445DW, and GARLK1412DW). This is attributed to suspended sediment in the inflowing Missouri River settling out in the reservoir as current velocities slow. The surface waters near Garrison Dam are significantly clearer than the upstream regions of the reservoir. Under the conditions that were monitored during 2010, it appears that sites GARLK1512DW and GARLK1481DW were in the riverine zone; site GARLK1445DW was in the transition zone; and sites GARLK1412DW and GARLK1390A were in the lacustrine zone of the reservoir.

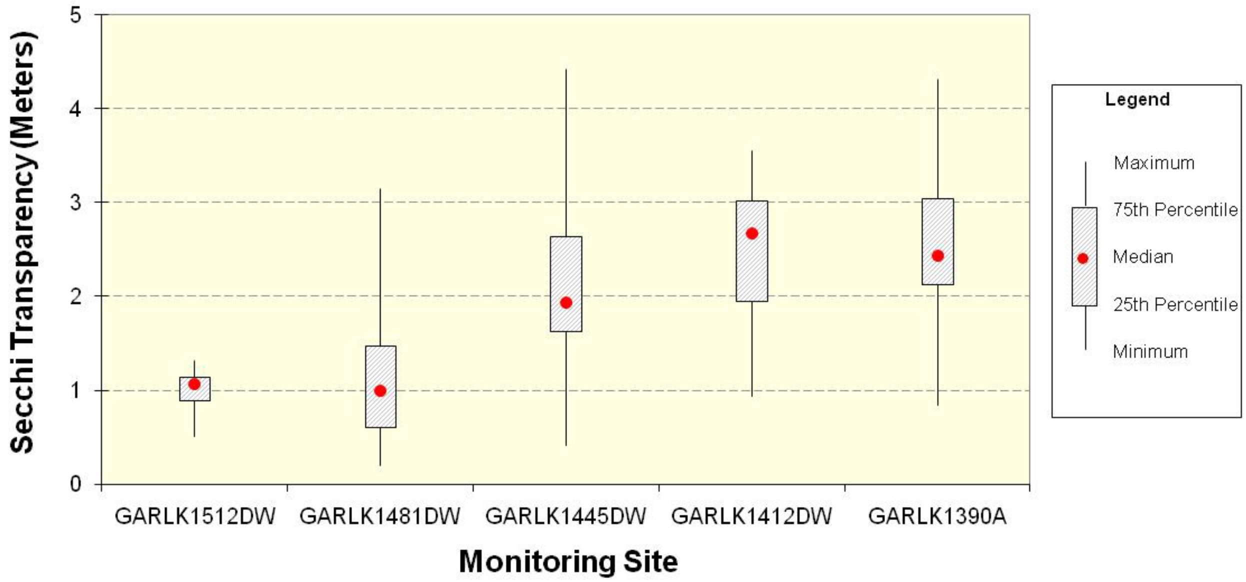


Figure 5-8. Box plot of Secchi transparencies measured in Lake Sakakawea during the 5-year period 2006 through 2010.

5.3.2.1.5.2 Turbidity

Monthly (May through September) longitudinal contour plots were prepared from the depth-profile turbidity measurements taken at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, GARLK1512DW, and GARNFMORRR1 during 2010 (Plate 87, Plate 88, Plate 89, Plate 90, and Plate 91). As seen in the contour plots, turbidity levels in Lake Sakakawea vary longitudinally from the dam to reservoir's upstream reaches. Turbidity levels are significantly higher in the upstream reaches of the reservoir as compared to the area near the dam. This is attributed to the turbid conditions of the inflowing Missouri River. Given the low chlorophyll *a* concentrations monitored in Lake Sakakawea, turbidity in the reservoir appears to be largely due to suspended inorganic material.

5.3.2.1.6 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Lake Sakakawea during the summer were compared. Near-surface conditions were represented by samples collected within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 1-meter of the reservoir bottom. The compared samples were collected at the near-dam site GARLK1390A during the 5-year period 2006 through 2010. During the period a total of 19 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Plate 92). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for water temperature, dissolved oxygen, ORP, and pH. Parameters that were significantly lower in the near-bottom water of Lake Sakakawea included: water temperature ($p < 0.001$), dissolved oxygen ($p < 0.001$), and pH ($p < 0.001$). ORP was significantly higher ($p < 0.001$) in the near-bottom water.

5.3.2.1.7 Reservoir Trophic Status

Trophic State Index (TSI) values for Lake Sakakawea were calculated from monitoring data collected during the 5-year period 2006 through 2010 (Table 5-7). The calculated TSI values indicate that the lacustrine zone of the reservoir (i.e., sites GARLK1390A and GARLK1412DW) is mesotrophic, the transition zone (i.e., site GARLK1445DW) is mesotrophic, and the riverine zone (i.e., site GARLK1481DW and GARLK1512DW) is eutrophic. It is noted that the total phosphorus nutrient guideline defined by North Dakota for lake improvement or management (i.e., 0.02 mg/l) was regularly exceeded throughout Lake Sakakawea (Plate 68, Plate 69, Plate 70, Plate 71, and Plate 72).

Table 5-7. Mean Trophic State Index (TSI) values calculated for Lake Sakakawea. TSI values are based on monitoring at the identified four sites during the 5-year period 2006 through 2010.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
GARLK1390A	48	50	50	50
GARLK1412DW	48	47	51	48
GARLK1445DW	49	48	52	50
GARLK1481DW	62	52	59	58
GARLK1512DW	61*	53*	61*	58*

Note: See Section 4.1.4 for discussion of TSI calculation.
* Based on 2010 data only.

5.3.2.1.8 Plankton Community

5.3.2.1.8.1 Phytoplankton

Phytoplankton grab samples were collected from Lake Sakakawea at five sites (i.e., GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARLK1512DW) during the spring and summer of the 5-year period 2006 through 2010 (Plate 93, Plate 94, Plate 95, Plate 96, and Plate 97). Taxa identified in the collected phytoplankton samples were from seven taxonomic divisions: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The relative abundance of phytoplankton, based on biovolume, in samples collected from Lake Sakakawea in May, July, and September 2010 is shown in Figure 5-9. Diatoms (Bacillariophyta) are by far the most dominant phytoplankton group present in Lake Sakakawea. Major phytoplankton genera sampled in Lake Sakakawea during 2010 (i.e., genera comprising more than 10% of the total biovolume of at least one sample) included the Bacillariophyta *Asterionella, Aulacoseria, Cyclotella, Fragilaria, and Tabellaria*; Cryptophyta *Rhodomonas*; Cyanobacteria *Anabaena* and *Aphanizomenon*; and Pyrrophyta *Ceratium*. No concentrations of the cyanobacteria toxin microcystin above 1 ug/l were monitored in Lake Sakakawea during the 5-year period 2006 through 2010 (Plate 68, Plate 69, Plate 70, Plate 71, and Plate 72).

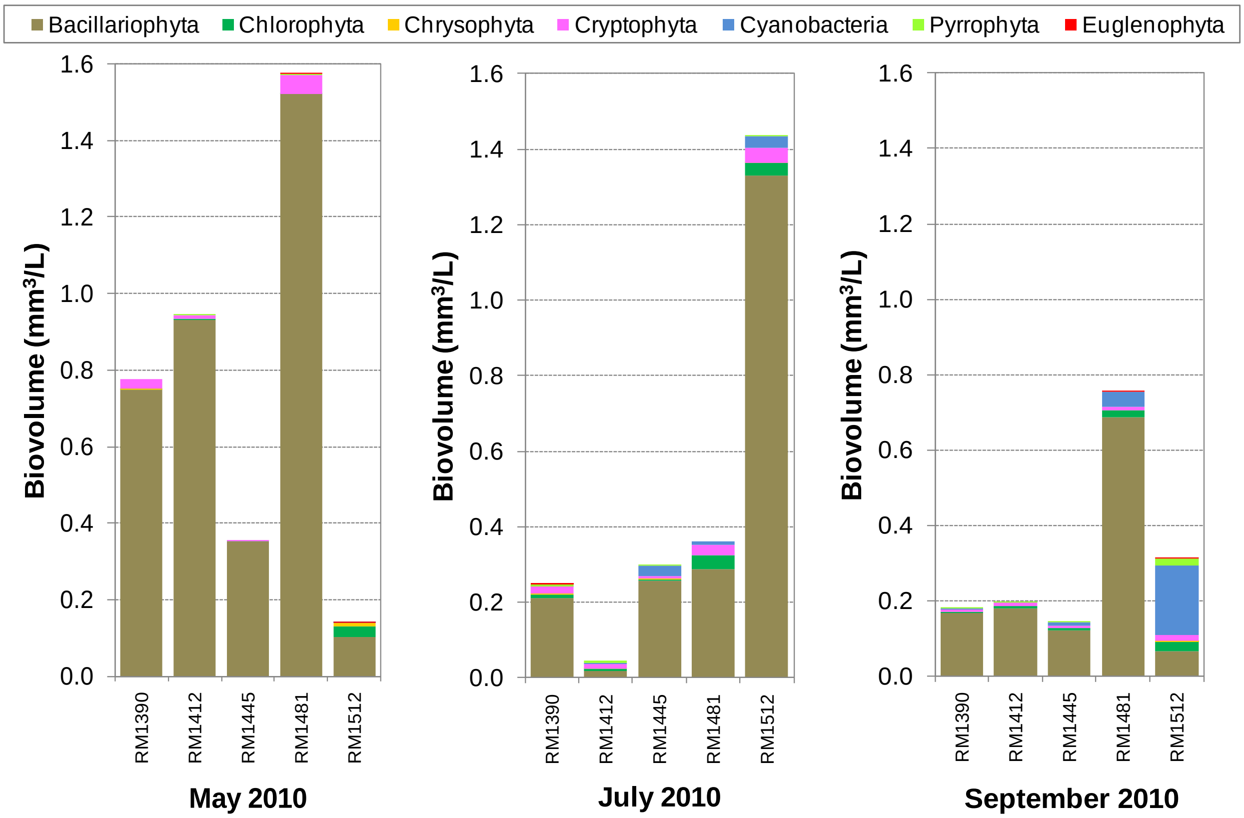


Figure 5-9. Relative abundance of phytoplankton in samples collected from Lake Sakakawea during 2010.

5.3.2.1.8.2 Zooplankton

Zooplankton vertical-tow samples were collected from Lake Sakakawea at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARLK1512DW in May, July, and September of 2010 (Plate 98). The sampled zooplankton included three taxonomic groupings: Cladocerans, Copepods, and Rotifers. The relative abundance of these three taxonomic grouping in the zooplankton samples collected in 2010 is shown in Figure 5-10. Cladocerans and copepods dominated the zooplankton community in Lake Sakakawea. Major zooplankton species sampled in Lake Sakakawea during 2010 (i.e., species comprising more than 10% of the total biomass of at least one sample) included Cladocerans *Bosmina longirostris*, *Daphnia pulex*, and *Daphnia retrocurva*; Copepods *Calanoid copepodid*, *Cyclopoid copepodid*, *Diacyclops*, *thomasi*, *Leptodiaptomus siciloides*, and *Mesocyclops edax*; and Rotifers *Asplanchna spp.*, *Brachionus calyciflorus*, *Brachionus urceolaris*, *Keratella quadrata*, *Polyarthra vulgaris*, and *Synchaeta spp.* Dominant species (i.e., species comprising more than 25% of the total biomass of at least one sample) included Cladocerans *Daphnia pulex*, *Daphnia retrocurva*; Copepods *Cyclopoid copepodid*, *Diacyclops thomasi*, and *Mesocyclops edax*; and Rotifers *Polyarthra vulgaris* and *Synchaeta spp.*

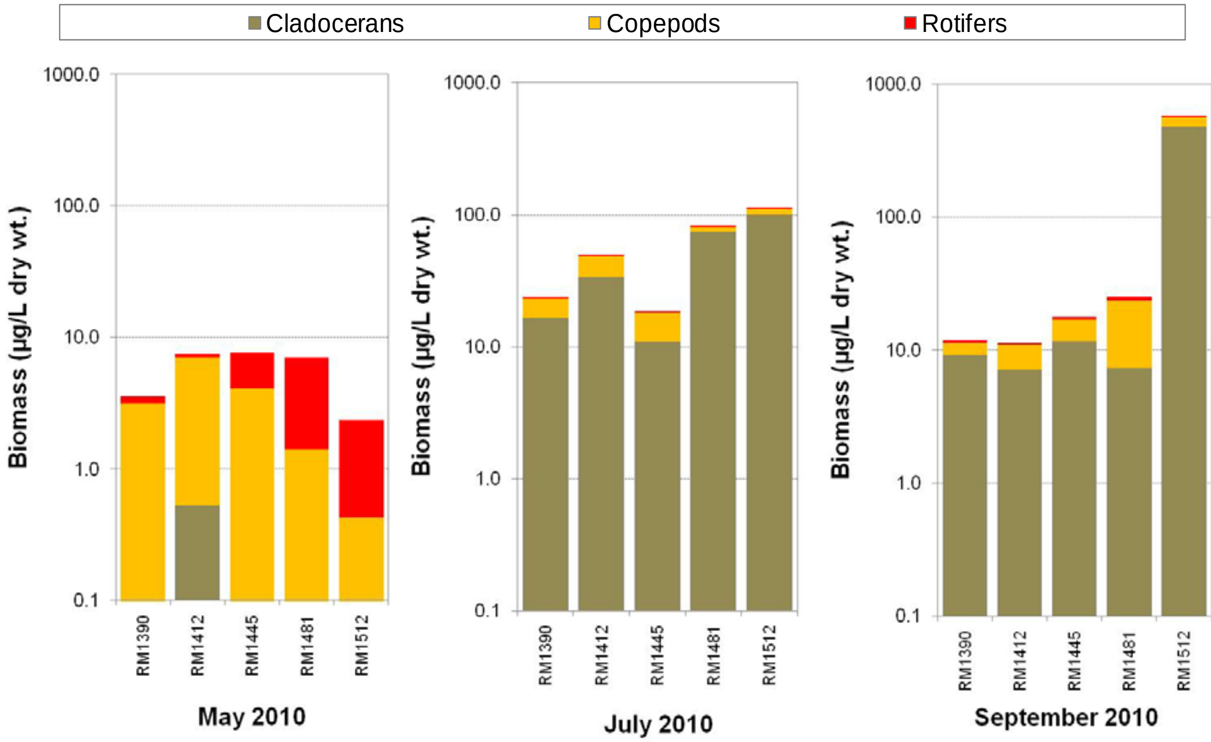


Figure 5-10. Relative abundance of zooplankton in samples collected from Lake Sakakawea during 2010**.**
Note: Y-axis is logarithmic scaled.

5.3.2.1.9 Impairment of Designated Water Quality Beneficial Uses

Based on the State of North Dakota's impairment assessment methodology (Section 4.1.6.3), the water quality conditions monitored in Lake Sakakawea during the 5-year period 2006 through 2010 indicate full support of all designated uses except coldwater fishery habitat. Coldwater fishery habitat was seemingly impaired during 2006, 2007, and 2008 due to higher temperatures and lower dissolved oxygen conditions in the hypolimnion which was reduced in volume. Since coldwater habitat only occurs in the hypolimnion of the reservoir during the summer, the size of the hypolimnion will directly determine the amount of coldwater habitat potentially available. Higher pool levels allowed for full support of coldwater fishery habitat in 2009 and 2010.

5.3.2.2 <u>Water Quality Trends (1980 through 2010)</u>

Water quality trends over the 31-year period of 1980 through 2010 were determined for Lake Sakakawea for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam, ambient monitoring site (i.e., site GARLK1390A). Plate 99 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, Lake Sakakawea did not exhibit significant trends for any of the four parameters. Over the 31-year period, the reservoir has generally remained in a mesotrophic state.

5.3.3 EXISTING WATER QUALITY CONDITIONS OF THE MISSOURI RIVER INFLOW TO LAKE SAKAKAWEA

5.3.3.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions that were monitored in the Missouri River near Williston, ND (i.e., site GARNFMORRR1) monthly from May through September during the 5-year period 2006 through 2010 are summarized in Plate 100 and Plate 101. A review of these results indicated no major water quality concerns. It is noted that monitored levels of total aluminum greatly exceeded the acute total aluminum criterion for aquatic life protection; however, the monitored levels of dissolved aluminum were well below the criterion. It is not believed the monitored aluminum levels are indicative of a water quality problem. It is also noted that very high levels of total iron were monitored. The high levels of total aluminum and iron are believed to be a natural condition associated with the geology and soils of the region.

5.3.3.2 Vertical Water Quality Variation in the Missouri River

Depth discrete water quality monitoring of the Missouri River at site GARNFMORRR1 was initiated in 2010. Near-surface and near-bottom grab samples were collected by lowering a finned-Van Dorn sampler from the U.S. Highway 85 Bridge over the Missouri River. The near-surface sample was collected just below the water surface and the near bottom sample was collected within ½-meter of the river bottom

Paired near-surface and near-bottom water quality samples collected at site GARNFMORRR1 during 2010 were compared. Three paired samples (June, July, and August) were collected during 2010. Box plots were constructed to display the distribution of the paired near-surface and near-bottom samples for selected non-particulate-associated (i.e., water total dissolved solid, dissolved sulfate, and dissolved phosphorus) and particulate-associated (i.e., total Kjeldahl nitrogen, total phosphorus, total suspended solids, total suspended sediment, and total organic carbon) constituents (Plate 102). Anecdotally, the box plots indicate no significant depth variation in the non-particulate- associated constituents. The box plots of the particulate-associated constituents indicate total Kjeldahl nitrogen, total suspended solids, and total suspended sediment have a higher distribution for the bottom samples. A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were not found to be significantly different for any parameter. It is noted that the small sample size limited the power of the applied statistical method to test for significant differences, and more testing will be done in the future as additional samples are collected.

The near-surface and near-bottom concentrations of the particulate-associated constituents total phosphorus, total Kjeldahl nitrogen, total suspended sediment, total suspended solids, and total organic carbon measured at site GARNFMORRR1 were plotted against the flow of the Missouri River at the time of sampling (Plate 103). Except for one TOC sample, near-bottom concentrations of the particulate-associated constituents were higher than the near-surface levels during low and moderate flow.

5.3.3.3 Missouri River Inflow Nutrient Flux Conditions

Nutrient flux rates for the Missouri River inflow to Lake Sakakawea over the 5-year period 2006 through 2010 were calculated based on near-surface water quality samples collected near Williston, ND (i.e. site GARNFMORRR1) and the instantaneous flow conditions at the time of sample collection (Table 5-8). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its

transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) are likely higher nearer the river bottom, near-surface grab samples likely under estimate the "true" water-column composite concentration for these constituents. Thus, the flux rates given for total phosphorus and total organic carbon in Table 5-8 should be considered minimum estimates with the actual flux rates likely being higher. The maximum flux rates for all the constituents are believed to be attributed to higher nonpoint-source loadings during runoff conditions.

Table 5-8. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Williston, ND (i.e., site GARNFMORRR1) during April through September over the 5-year period 2006 through 2010.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)[1]	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)[1]
No. of Obs.	29	29	29	29	29	28	28
Mean	20,392	0.0262	0.4407	0.0624	0.1772	0.0133	1.7830
Median	14,530	0.0065	0.4150	0.0200	0.1129	0.0070	1.3415
Minimum	7,649	n.d.	0.0732	n.d.	0.0152	n.d.	0.4862
Maximum	52,320	0.2193	1.4073	0.3000	0.7405	0.0707	5.6598

Note: Nondetect values set to 0 for flux calculations.
(1) Flux calculations for total phosphorus and total organic carbon are biased estimates based on sampled near-surface concentrations and should be considered minimum estimates of total flux (see text for further discussion).

5.3.3.4 Continuous Water Temperature Monitoring of the Missouri River at USGS Gage Site 06330000 near Williston, North Dakota

Through an agreement with the USGS, a water temperature monitoring probe was added to the USGS's gage (06330000) on the Missouri River near Williston, ND (i.e., site GARNFMORRR1). Beginning in 2005, water temperature measurements were recorded at the site. Plate 104, Plate 105, Plate 106, Plate 107, and Plate 108, respectively, plot mean daily water temperature and river discharge determined for 2006, 2007, 2008, 2009, and 2010.

5.3.4 WATER QUALITY AT THE GARRISON POWERPLANT

5.3.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 109 and Plate 110 summarize the water quality conditions that were monitored from water discharged through Garrison Dam during the 5-year period 2006 through 2010. The monitored water quality conditions do not indicate any significant water quality concerns. All dissolved oxygen concentrations measured during the 2006 through 2010 period were above 5 mg/l. The maximum water temperature measured during the 5-year period was 18.2°C. The monitored water temperatures are believed supportive of the coolwater fishery that exists in the Garrison Dam tailwaters.

5.3.4.2 Impairment of Designated Water Quality Beneficial Uses

Based on the State of North Dakota's impairment assessment methodology (Section 4.1.6.3), the water quality conditions monitored at the Garrison powerplant during the 5-year period 2006 through 2010 did not indicate any impairment of designated water quality beneficial uses.

5.3.4.3 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Semiannual time series plots for temperature and dam discharge monitored hourly at the Garrison powerplant during the 8-year period of 2003 through 2010 were constructed (Plate 111 - Plate 125). Monitored water temperatures showed seasonal cooling and warming through each calendar year. Daily water temperatures remained fairly stable during the winter, early spring, and late fall and exhibited considerable variability during the late spring, summer, and early fall. When thermal stratification becomes established in Lake Sakakawea during the late spring, the temperature of the water discharged through the dam becomes highly dependent upon the discharge rate of the dam. This indicates that the vertical extent of the withdrawal zone in the reservoir is dependent upon the discharge rate of the dam. This is believed to be a result of the design of the intake structure (i.e., bottom withdrawal) and the presence of the submerged intake channel leading to the intake structure (Figure 5-6). Water is likely drawn from an extended vertical zone in Lake Sakakawea year-round, but is only evident in the temperatures monitored at the powerplant during thermal stratification of the reservoir in the summer. A decrease in the daily variation of the monitored temperatures in the summers of 2005 through 2009 occurred after the installation of plywood barriers on the lower portion of the trash racks in front of penstocks 2 and 3 in 2005 and penstock 1 in 2007.

Semiannual time series plots for dissolved oxygen and dam discharge monitored hourly at the Garrison powerplant during the 8-year period of 2003 through 2010 were also constructed (Plate 126 - Plate 140). Dissolved oxygen levels remained relatively high and stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall. The lowest dissolved oxygen levels occurred during the late summer/early fall period. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. The decreasing dissolved oxygen in the July to September period is attributed to ongoing degradation of dissolved oxygen in the lower hypolimnion in Lake Sakakawea as the summer progressed. Water is withdrawn from Lake Sakakawea into the dam's power tunnels approximately 2 feet above the reservoir bottom. During the late summer, dissolved oxygen levels were highly correlated to dam discharge rates in 2003, 2004, 2009, and 2010; and not as correlated in 2005, 2006, 2007, and 2008. This is attributed to the implementation of the short-term water quality management measures in 2005 through 2009. In early October 2009, the plywood barriers were removed from the lower portions of the trash racks front of Units 1, 2, and 3. This seemingly allowed water with lower dissolved oxygen levels to be pulled from the lower hypolimnion in October 2009; especially during low discharge periods. This is seen in Plate 138 where dissolved oxygen levels below 5 mg/l were monitored in early October.

5.3.4.4 Discharge of Water through the Five Penstocks at Garrison Dam during the Period Plywood Barriers were in Place

The volume of water that was discharged through each of the five penstocks during the summer over the 5-year period the plywood barriers were in place is shown Table 5-9.

Table 5-9. Volume of water (ac-ft) discharged through the five Units at Garrison Dam during June, July, August, and September over the 5-year period 2005 through 2009.

Month	Volume of Water Discharged (ac-ft)			Percent of Total Water Discharged	
	Units with Barriers	Units with No Barriers	Total	Units with Barriers	Units with No Barriers
2005					
June	230,708	661,713	892,421	0.26	0.74
July	308,887	624,407	933,294	0.33	0.67
August	268,035	685,744	953,779	0.28	0.72
September	436,659	403,104	839,763	0.52	0.48
2006					
June	694,472	486,661	1,181,133	0.59	0.41
July	815,368	449,544	1,264,912	0.64	0.36
August	810,942	504,405	1,315,347	0.62	0.38
September	594,305	483,558	1,077,863	0.55	0.45
2007					
June	761,565	192,863	954,428	0.80	0.20
July	781,339	198,866	980,205	0.80	0.20
August	742,178	241,912	984,090	0.75	0.25
September	453,800	239,363	693,163	0.65	0.35
2008					
June	816,793	36,728	853,521	0.96	0.04
July	824,658	13,338	837,996	0.98	0.02
August	576,549	278,799	855,347	0.67	0.33
September	374,784	359,397	734,181	0.51	0.49
2009					
June	525,668	421,573	947,241	0.55	0.45
July	536,678	428,129	964,807	0.56	0.44
August	554,616	432,190	986,806	0.56	0.44
September	464,676	413,185	877,861	0.53	0.47
October (1-14)	183,711	168,344	352,056	0.52	0.48

5.3.4.5 Comparison of Summer Temperature and Dissolved Oxygen Conditions Monitored at the Garrison Powerplant

Plate 141 and Plate 142 show plots of hourly water temperatures measured at the Garrison powerplant during the period of June through October for 2003 through 2010. During the period 2005 through 2008, it is evident that the installation of the plywood barriers in 2005 reduced the variability and raised the temperature of the water passed through Garrison Dam and discharged to the Missouri River downstream during the summer. The increase in temperature was, on average, about 2°C. The coolest discharges occurred in 2009 and 2010. The cooler water temperatures in 2009, the last year the plywood barriers were in place, are attributed to three things: 1) during 2009 water discharged through Garrison Dam was not maximized through the penstocks with the plywood barriers (Table 5-9); 2) the summer of 2009 was unusually cool and seemingly resulted in cooler lake water temperatures; and 3) 2009 was the only year when plywood was installed that “normal” pool elevations occurred all year and resulted in a larger and cooler hypolimnetic volume.

Plate 143 and Plate 144 show a plot of hourly dissolved oxygen concentrations measured at the Garrison powerplant during the period of June through October for 2003 through 2010. It is evident that the installation of the short-term water quality management measures in 2005 raised the dissolved oxygen concentrations of water passed through Garrison Dam and discharged to the Missouri River downstream,

especially later in the summer. The plywood barriers allowed epilimnetic water, higher in dissolved oxygen, to be drawn into the power tunnel intakes and then to be discharged from the dam. Although the short-term water quality management measures were implemented to preserve coldwater habitat in Lake Sakakawea, they also had the probable benefit of preventing dissolved oxygen levels below the State of North Dakota's water quality standards criterion (i.e., 5 mg/l) from occurring in the Garrison Dam tailwaters during late summer low flow releases.

5.3.4.6 Comparison of Monitored Inflow and Outflow Temperatures of the Missouri River at Lake Sakakawea

Plate 145, Plate 146, Plate 147, Plate 148, and Plate 149, respectively, plot the mean daily water temperatures monitored at the Missouri River near Williston, ND (site GARNFMORRR1) and the Garrison Dam powerplant (site GARPP1) for 2006, 2007, 2008, 2009, and 2010. Inflow temperatures of the Missouri River to Lake Sakakawea are generally warmer than the outflow temperatures of Garrison Dam during the period of April through September. Outflow temperatures of the Garrison Dam discharge are generally warmer than the inflow temperatures of the Missouri River during the period of October through March. A maximum temperature difference occurs in the summer when the Missouri River inflow temperature is about 10°C warmer than the Garrison Dam outflow temperature.

5.3.4.7 Nutrient Flux Conditions of the Garrison Dam Discharge to the Missouri River

Nutrient flux rates for the Garrison Dam discharge to the Missouri River over the 5-year period 2006 through 2010 were calculated based on samples taken from the Garrison powerplant (i.e. site GARPP1) and the dam discharge at the time of sample collection (Table 5-10). During this 5-year period, all water discharged at Garrison Dam was through the powerplant. The samples collected in the powerplant are taken from the raw water supply line and are believed to be unbiased regarding particulate-associated constituents. Therefore, the flux rates calculated for the Garrison Dam discharge give an unbiased estimate of the flux rates for all the constituents, including total phosphorus and total organic carbon. The maximum flux rates for all the constituents are believed to be attributed to higher dam discharges.

Table 5-10. Summary of nutrient flux rates (kg/sec) calculated for the Garrison Dam discharge to the Missouri River (i.e., site GARPP1) during January through December over the 5-year period 2006 through 2010.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	49	49	49	49	49	47	48
Mean	16,824	0.0166	0.1960	0.0330	0.0114	0.0060	1.5860
Median	13,528	n.d.	0.1349	0.0306	0.0060	n.d.	1.1739
Minimum	9,076	n.d.	n.d.	n.d.	n.d.	n.d.	0.3461
Maximum	37,300	0.1534	0.7438	0.1056	0.0810	0.0439	4.6131

Note: Nondetectable values set to 0 for flux calculations.

5.3.5 WATER QUALITY IN THE MISSOURI RIVER DOWNSTREAM OF GARRISON DAM

5.3.5.1 Water Temperatures Monitored at Garrison Dam and the USGS Gage Station at Bismarck, North Dakota

Through an agreement with the USGS, a water temperature monitoring probe was added to the USGS's gage on the Missouri River at Bismarck, ND in 2005. The USGS gage at Bismarck, ND is located at RM1314.7 and is approximately 75 miles downstream of Garrison Dam. Plate 150, Plate 151, Plate 152, Plate 153, and Plate 154, respectively, plot the mean daily flows and water temperatures monitored at the Garrison powerplant and USGS gage at Bismarck, ND in 2006, 2007, 2008, 2009, and 2010. Annually, the mean daily water temperature of the Missouri River at Bismarck is warmer than the Garrison Dam discharge from April through August and generally cooler from September through March. During the summers of 2006, 2007, 2008, 2009, and 2010 mean daily water temperatures at Bismarck were, respectively, up to 6°C, 8°C, 7°C, 10°C, and 10°C warmer than the Garrison Dam discharge. The lower summer temperature differences in 2006, 2007, and 2008 are attributed to the full implementation of the short-term water quality management measures at Garrison Dam and the lower pool elevations in Lake Sakakawea.

5.3.5.2 Water Temperatures Monitored in the Reach from Garrison Dam to Bismarck, ND in 2006, 2007, 2009, and 2010

As part of their fisheries management program, the North Dakota Game and Fish Department (NDGFD) monitored water temperatures in the Missouri River from Garrison Dam (RM1389) to Beaver Bay (RM1259). Sites monitored in 2006 (May through September) included Garrison Dam Tailwaters (RM1390), Stanton (RM1372), Washburn (RM1355), Wilton (RM1344), Burnt Creek, and North Beaver (RM1260). Sites monitored in 2007 (May through September) included Garrison Dam Tailwaters (RM1390), Stanton (RM1372), Washburn (RM1355), Wilton (RM1344), and Fox Island (RM1312). Temperature monitors that were deployed by the NDGFD in 2008 failed and no data were recorded. Sites monitored in 2009 (May through mid-October) included Garrison Dam Tailwaters (RM1390), Stanton (RM1372), Washburn (RM1355), Wilton (RM1344), Fox Island (RM1312) and Kimball (RM1300). Sites monitored in 2010 (May through mid-October) included Garrison Dam Tailwaters (RM1390), Stanton (RM1372), Washburn (RM1355), Wilton (RM1344), and Kimball (RM1300). Plate 155, Plate 156, Plate 157, and Plate 158, respectively, plot mean daily water temperatures monitored in the Missouri River downstream from Garrison Dam in 2006, 2007, 2009, and 2010.

5.4 OAHE

5.4.1 BACKGROUND INFORMATION

5.4.1.1 Project Overview

Oahe Dam is located on the Missouri River at RM 1072.3 in central South Dakota, 6 miles northwest of Pierre, SD. The closing of Oahe Dam in 1958 resulted in the formation of Oahe Reservoir (Lake Oahe). When full, the reservoir is 231 miles long, covers 374,000 acres, and has 2,250 miles of shoreline. Table 5-11 summarizes how the surface area, volume, mean depth, and retention time of Lake Oahe vary with pool elevations. The reservoir has recovered from recent drought conditions of the past decade and was at a pool elevation of 1607.4 at the end of December 2009. This is only 0.1 feet below the top of the Carryover Multiple Use Zone (1607.5 ft-NGVD29). Major inflows to the reservoir are the Missouri and Cheyenne Rivers. Water discharged through Oahe Dam for power production is withdrawn from Lake Oahe at elevation 1524 ft-NGVD29, approximately 114 feet above the reservoir bottom. Figure 5-11 shows a schematic drawing and photo of Oahe Dam and the power intake structure.

Table 5-11. Surface area, volume, mean depth, and retention time of Lake Oahe at different pool elevations based on 1989 bathymetric survey.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1620	374,135	23,136,960	61.8	1.36
1615	350,960	21,323,520	60.8	1.25
1610	325,765	19,630,460	60.3	1.15
1605	300,030	18,068,750	60.2	1.06
1600	281,010	16,618,390	59.1	0.98
1595	260,715	15,265,460	58.6	0.90
1590	245,190	14,002,600	57.1	0.82
1585	229,085	12,816,650	55.9	0.75
1580	213,150	11,711,030	54.9	0.69
1575	196,915	10,686,750	54.3	0.63
1570	182,933	9,737,896	53.2	0.57
1565	168,523	8,859,708	52.6	0.52
1560	155,510	8,049,792	51.8	0.47
1555	141,688	7,308,917	51.6	0.43
1550	133,628	6,622,830	49.6	0.39
1545	124,869	5,976,361	47.9	0.35
1540	116,560	5,373,030	46.1	0.32

Average Annual Inflow (1967 through 2010) = 17.93 Million Acre-Feet
Average Annual Outflow: (1967 through 2010) = 17.04 Million Acre-Feet
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1620-1617 ft-NGVD29), Annual Flood Control and Multiple Use Zone (elev. 1617-1607.5 ft-NGVD29), Carryover Multiple Use Zone (elev. 1607.5-1540 ft-NGVD29), and Permanent Pool Zone (elev. 1540-1415 ft-NGVD29). All elevations are in the NGVD 29 datum.

Lake Oahe and Oahe Dam are authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. Over the period 1967 through 2010, the seven generating units at Oahe Dam have produced an annual average 2.618 million MWh of electricity. The recent drought in the interior western United States curtailed releases and power production at the Missouri River mainstem system projects, including Oahe. Power production at the Oahe Dam generating units averaged an annual 1.626 MWh over the 5-year period 2006 through 2010. Habitat for one endangered species, interior least tern, and one threatened species, piping plover, occurs within the project area. Lake Oahe is used as a water supply by the towns of Fort Yates, ND (RM1244); Wakpala, SD (RM1198); Mobridge, SD (RM1193), and Huron, SD (RM1074), SD. The intake for the WEB Water System is at RM 1184 (serves 45 towns and over 7,000 rural households), and the intake for the Cheyenne River Tribe Mni Water Company is at RM 1110 (Eagle Butte, LaPlante, Swiftbird, Whitehorse, Promise, Dupree, Iron Lightning, Thunder Butte, Faith, Howes, Isabel, Takina, Cherry Creek, Bridger, Lantry, Ridgeview, Red Elm, Red Scaffold, Blackfoot, and Parade, SD). Lake Oahe is an important recreational resource and a major visitor destination in South Dakota.

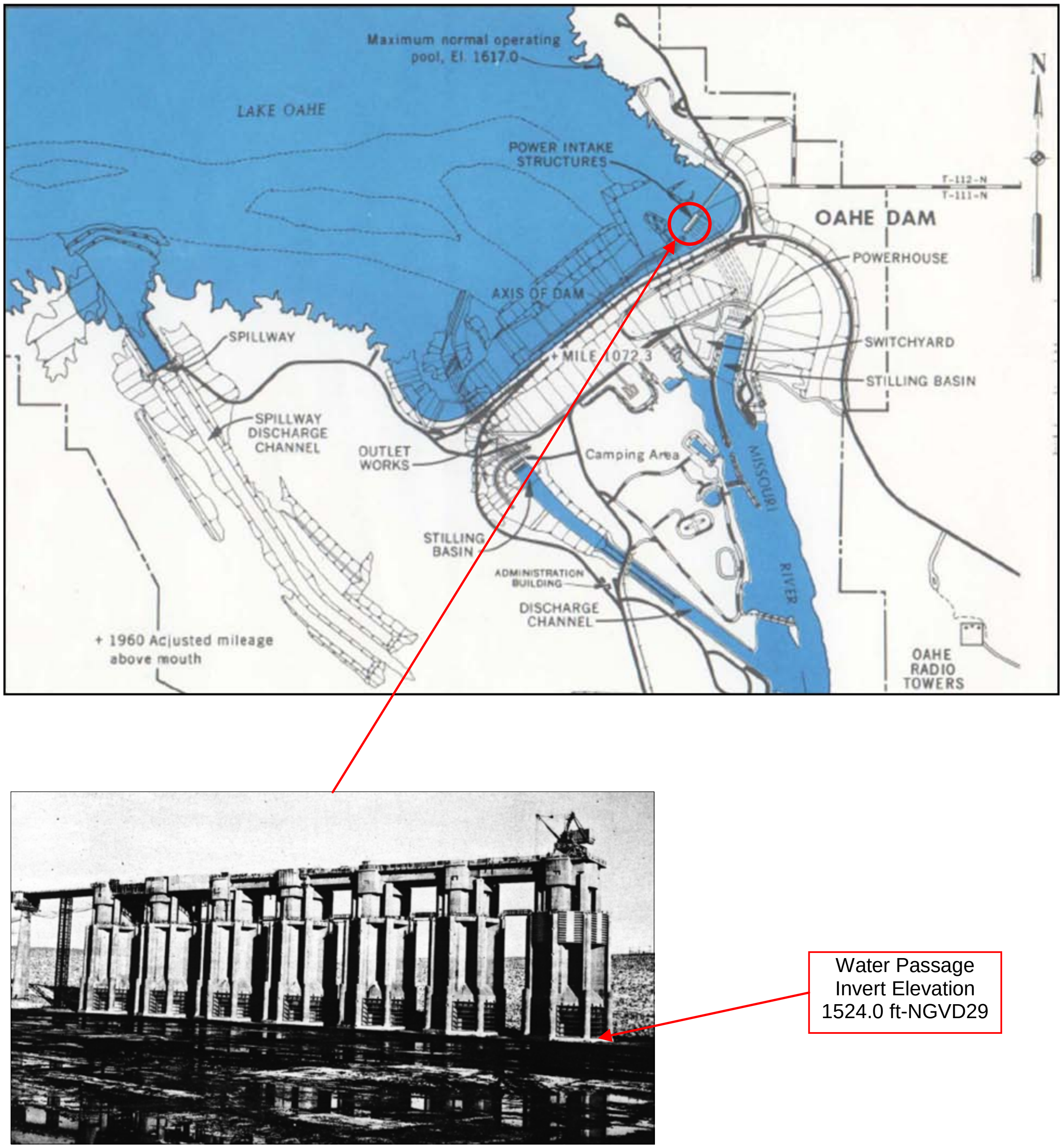


Figure 5-11. Location and photo of the power intake structure at Lake Oahe.

5.4.1.2 Water Quality Standards Classifications and Section 303(d) Listings

5.4.1.2.1 Lake Oahe

Under normal pool levels, Lake Oahe runs along the Missouri River from approximately RM1072 to RM1290, and crosses the North Dakota/South Dakota border which is at RM1232. Therefore under normal pools about 25 and 75 percent of the length of the reservoir is respectively in North Dakota and South Dakota. Water quality standards from each State respectively apply to the portion of the reservoir in each state.

The State of North Dakota has classified Lake Oahe as a Class 1 lake. As such, the reservoir is to be protected for a coldwater fishery; swimming, boating, and other water recreation; irrigation; stock watering; wildlife; and municipal or domestic use after appropriate treatment. Pursuant to Section 303(d) of the Federal CWA, North Dakota has not placed the Lake Oahe on the State's list of impaired waters. The State of North Dakota has issued a fish consumption advisory for Lake Oahe due to mercury concerns.

South Dakota has classified the Missouri River impoundments within the State as flowing streams and not reservoirs (South Dakota Administrative Rules 74:51:01:43). The following water quality-dependent beneficial uses have been designated for Lake Oahe in South Dakota's water quality standards: domestic water supply waters, coldwater permanent fish life propagation waters, immersion recreation waters, limited-contact recreation waters, commerce and industry waters, agricultural water supply (i.e., irrigation and stock watering), and fish and wildlife propagation. The State of South Dakota has not placed the reservoir on the State's Section 303(d) list of impaired waters and has not issued a fish consumption advisory for the reservoir. However, the Cheyenne River Sioux Tribe has issued a fish consumption advisory for Lake Oahe and the Cheyenne and Moreau Rivers. Tribal lands of the Cheyenne River Sioux are located along the west side of Lake Oahe between the Moreau and Cheyenne Rivers.

5.4.1.2.2 Missouri River Downstream of Oahe Dam

The following beneficial uses have been designated by South Dakota in their water quality standards for the Missouri River from Oahe Dam to Lake Sharpe: recreation (i.e., immersion and limited-contact), coldwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of South Dakota has not placed the river on its Section 303(d) list of impaired waters and has not issued a fish consumption advisory for the river.

5.4.1.3 Ambient Water Quality Monitoring

The District has monitored water quality conditions at the Oahe Project since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow to and outflow from the reservoir. A 3-year intensive water quality survey was completed at the Oahe Project in 2007, and the findings of the intensive survey are available in the separate report, "Water Quality Conditions Monitored at the Corps' Oahe Project in South Dakota during the 3-year period 2005 through 2007" (USACE, 2008). Figure 5-12 shows the location of sites at the Oahe Project that have been monitored by the District for water quality during the past 5 years (i.e., 2006 through 2010). Water quality monitoring upstream of Mobridge, South Dakota (i.e., RM1196) was not conducted prior to 2009. Drought conditions and low pool levels during this period resulted in the reservoir's upstream boundary receding to near the North Dakota/South Dakota border. The District added a monitoring site on Lake Oahe near Beaver Creek (RM1256) in 2009. The new monitoring site is west of the town of Linton, ND. The near-dam location (i.e., site OAHLK1073A) has been continuously monitored since 1980.

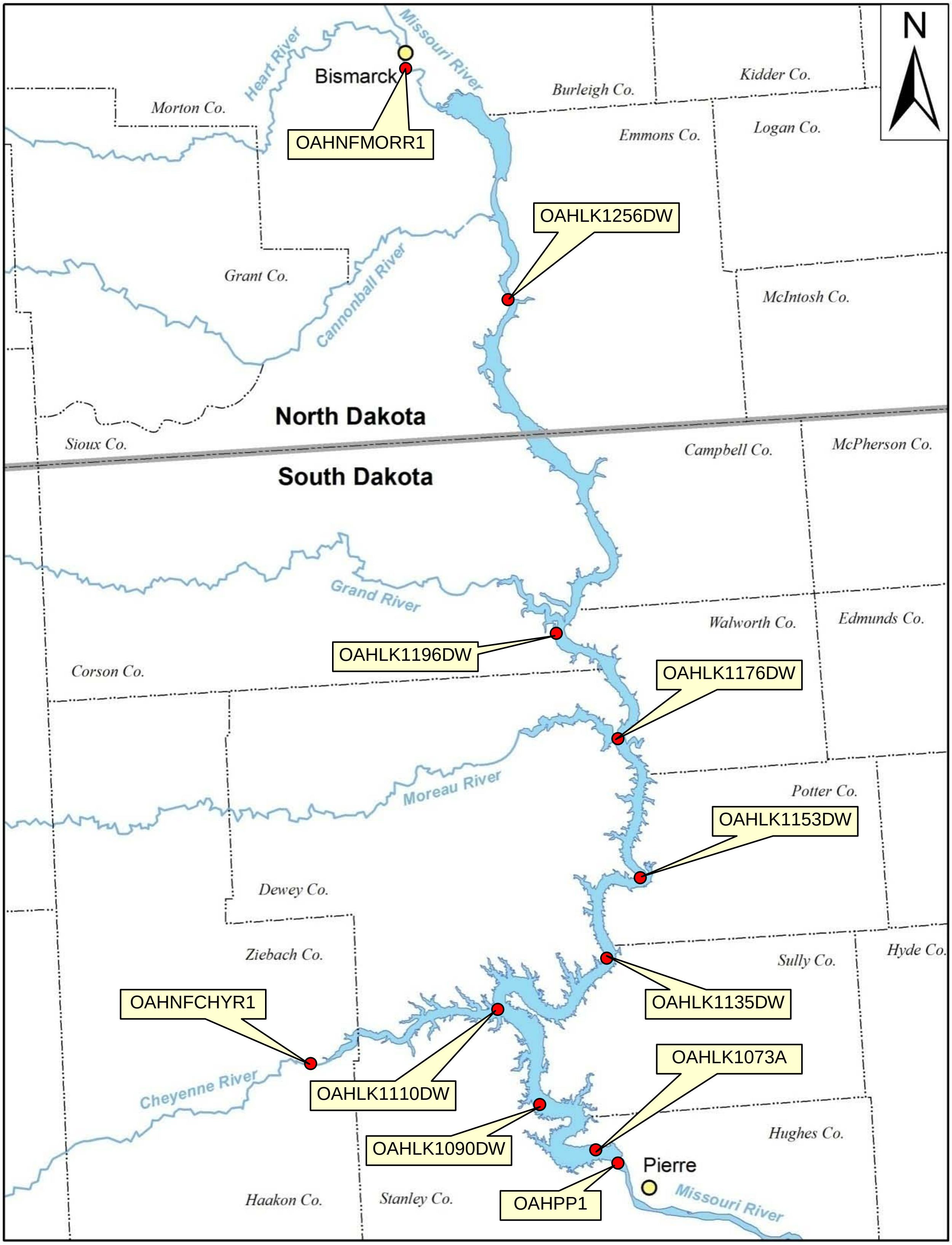


Figure 5-12. Location of sites where water quality monitoring was conducted by the District at the Oahe Project during the 5-year period 2006 through 2010.

5.4.2 WATER QUALITY IN LAKE OAHE

5.4.2.1 Existing Water Quality Conditions

5.4.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Water quality conditions that were monitored in Lake Oahe at sites OAHLK1073A, OAHLK1090DW, OAHLK1110DW, OAHLK1135DW, OAHLK1153DW, OAHLK1176DW OAHLK1196DW, and OAHLK1256DW from May through September during the 5-year period 2006 through 2010 are summarized in Plate 159, Plate 160, Plate 161, Plate 162, and Plate 163. A review of these results indicated possible water quality concerns regarding water temperature and dissolved oxygen for the support of Coldwater Permanent Fish Life Propagation. Water temperatures in the epilimnion of the reservoir regularly exceed 18.3°C in the summer, while temperatures in the hypolimnion are less than 18.3°C. Dissolved oxygen levels in the hypolimnion continually degrade along the reservoir bottom as summer progresses and fall below 7.0 mg/l in late summer (i.e., occurred in non-spawning area outside the spawning season for coldwater species). During the 5-year period, dissolved oxygen levels remained above 6.0 mg/l in the hypolimnion in the area of the reservoir near Oahe Dam (Plate 159 and Plate 160). Dissolved oxygen concentrations regularly fell below 6 mg/l in the middle and upstream reaches of the hypolimnion (Plate 161 and Plate 162). As the summer progressed, conditions of lower dissolved oxygen moved up from the reservoir bottom into the hypolimnion. Due to the reduced water depth a hypolimnion did not form in the upstream reaches of Lake Oahe (Plate 163). Conditions supportive of Coldwater Permanent Fish Life Propagation (i.e., water temperature ≤18.3°C and dissolved oxygen ≥ 6 mg/l) were present in 100, 91, 74, 35, and 33 percent of the depth-profile measurements respectively taken at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, and OAHLK1256DW. The lowest dissolved oxygen concentration measured during the 5-year period at the five sites was 1.2 mg/l, and occurred at site OAHLK1196DW in August 2010.

5.4.2.1.2 Summer Thermal Stratification

5.4.2.1.2.1 Monthly Longitudinal Temperature Contour Plots

Summer thermal stratification of Lake Oahe during 2010 is described by the monthly longitudinal temperature contour plots based on depth-profile temperature measurements taken in May, June, July, August, and September (Plate 164, Plate 165, Plate 166, Plate 167, and Plate 168). The contour plots were constructed along the length of the reservoir. As seen in the contour plots, water temperature in Lake Oahe varies longitudinally from the dam to the reservoir's upper reaches and vertically from the reservoir surface to the bottom. The near-surface water in the upper reaches of the reservoir warms up sooner in the spring than the near-surface water near the dam. By mid-summer a strong thermocline becomes established in the lower reaches of the reservoir, and the near-surface waters of the entire reservoir above the thermocline are a fairly uniform temperature. As the near-surface waters of the reservoir cool in the late summer, the thermocline is pushed deeper and these wind-mixed upper waters are fairly uniform in temperature. The vertical variation in temperature is most prevalent in the deeper area of the reservoir towards the dam where a strong thermocline becomes established during the summer. The shallower upper reaches of Lake Oahe do not exhibit much vertical variation of temperature during mid to late summer as wind action allows for complete mixing of the water column.

5.4.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Lake Oahe at the deep water area near the dam is described by the depth-profile temperature plots measured over the 5-year period 2006 through 2010. Depth-profile temperature plots measured during the summer months were compiled (Plate 169). The

plotted depth-profile measurements indicate that a significant temperature-depth gradient occurs in Lake Oahe in the near-dam lacustrine area during the summer, and a thermocline becomes established at a depth of 20 to 25 meters.

5.4.2.1.3 Summer Dissolved Oxygen Conditions

5.4.2.1.3.1 Monthly Longitudinal Dissolved Oxygen Contour Plots

Dissolved oxygen longitudinal contour plots were constructed along the length of Lake Oahe based on depth-profile measurements taken in May, June, July, August, and September of 2010 (Plate 170, Plate 171, Plate 172, Plate 173, and Plate 174). During the summer of 2010, dissolved oxygen conditions in Lake Oahe varied longitudinally from the dam to the reservoir's upper reaches and vertically from the reservoir surface to the bottom. Dissolved oxygen levels below 6 mg/l first appeared near the reservoir bottom in the middle reaches of the reservoir in July. As the summer progressed, dissolved oxygen concentrations below 6 mg/l expanded along the bottom in the middle reaches of the reservoir, but near-bottom dissolved oxygen concentrations at the dam remained above 6 mg/l. The occurrence of low dissolved oxygen concentrations in the near-bottom water of the middle reaches of Lake Oahe is attributed to the increased allochthonous organic loading in the transition zone of the reservoir and the lesser hypolimnetic volume available for assimilation of the oxygen demand. As this material decomposes, a "pool" of water with low dissolved oxygen levels accumulates near the bottom in this area of the reservoir. Decomposition of autochthonous organic matter also occurs in the lacustrine zone and results in dissolved oxygen degradation as the summer progresses, although at a slower rate than what occurs in the transition zone. The recovery of near-bottom dissolved oxygen concentrations to saturation levels takes longer in the deeper water nearer the dam because of the time needed for thermal stratification to breakdown and mixing within the water column to occur in the deeper water.

5.4.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Existing summer dissolved oxygen conditions in Lake Oahe at the deep-water area near the dam are described by the depth-profile dissolved oxygen plots measured over the 5-year period 2006 through 2010. Depth-profile dissolved oxygen plots measured during the summer months at site OAHLK1073A were compiled (Plate 175). Dissolved oxygen levels exhibited a gradient with depth and tended toward a negative heterograde to orthograde vertical distribution. During the 5-year period of 2006 through 2010, dissolved oxygen concentrations in the lower hypolimnion did not fall below 6 mg/l at site OAHLK1073A. The lowest dissolved oxygen concentration measured at this site over the past 5 years was 6.2 mg/l, which was measured at the reservoir bottom in September 2008.

5.4.2.1.4 Occurrence of Coldwater Permanent Fish Life Propagation Habitat in Lake Oahe

The most crucial period for the support of Coldwater Permanent Fish Life Propagation (CPFLP) habitat in Lake Oahe is when the reservoir begins to cool in late summer. As the thermocline moves deeper, the volume of the coldwater hypolimnion continues to decrease while the expanding epilimnion may not have cooled enough to be supportive of CPFLP habitat. At the same time, hypolimnetic dissolved oxygen concentrations are approaching their maximum degradation and low dissolved oxygen levels are moving upward from the reservoir bottom and "pinching off" coldwater habitat from below. This situation continues to worsen until the epilimnion cools enough to be supportive of CPFLP habitat and the reservoir eventually experiences fall turnover. The volume of the hypolimnion (i.e., CPFLP habitat) occurring in Lake Oahe during the summer decreases with lower pool levels.

The occurrence of CPFLP habitat (i.e., water temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l) in Lake Oahe was estimated from collected water temperature and dissolved oxygen depth-profile

measurements and defined reservoir elevation and volume relationships. Plate 176 displays a plot of pool elevations and the CPFLP habitat estimated to have been present in Lake Oahe during the summers of 2005 through 2010.

The occurrence of coldwater habitat in Lake Oahe is highly dependent on pool elevation. Since coldwater habitat only occurs in the hypolimnion of the reservoir during the summer, the size of the hypolimnion will determine the amount of coldwater habitat potentially available. The upper extent of the hypolimnion is delineated by the thermocline (i.e., zone of rapid temperature decline) which separates the colder hypolimnion from the warmer, less dense water of the epilimnion. Depending on climatic factors, the thermocline in an individual reservoir will generally be established at a similar depth from year to year. Therefore, a greater hypolimnetic volume will tend to occur under higher pool elevations and a lesser hypolimnetic volume will tend to occur under lower pool elevations. The pool elevation in late-spring and early summer when the thermocline first becomes established is especially important as later changes in pool elevations are mitigated somewhat by the stratification already established. A larger hypolimnetic volume also has a greater assimilative capacity for oxygen demanding materials which can degrade dissolved oxygen levels in the hypolimnion below the CPFLP habitat standard of 6 mg/l.

The relationship between the occurrence of CPFLP habitat and pool elevation is can be seen in the CPFLP habitat estimated to have occurred in Lake Oahe during 2005 through 2010 (Plate 176). The years with the highest pool elevations (i.e., 2009 and 2010) generally had the highest estimated occurrence of CPFLP habitat. The years with the lower pool elevations (i.e., 2005, 2006, 2007, and 2008) generally had the lowest estimated occurrence of CPFLP habitat. In late summer (i.e., September), the onset of fall turnover plays a significant role in the occurrence of CPFLP habitat in Lake Oahe. The year with the lowest pool elevation (i.e., 2006) had more estimated CPFLP in September than the years with the highest pool elevations (i.e., 2009 and 2010). This is attributed to fall turnover of Lake Oahe having completely occurred when monitored in 2006, and not having completely occurred when monitored in 2009 and 2010.

5.4.2.1.5 Water Clarity

5.4.2.1.5.1 Secchi Transparency

Figure 5-13 displays a box plot of the Secchi depth transparencies measured along Lake Oahe at the five sites OAHLK1256DW, OAHLK1196DW, OAHLK1153DW, OAHLK1110DW, and OAHLK1073A during the 5-year period 2006 through 2010. Secchi depth transparency increased in a downstream direction from the upper reaches of the reservoir to near the dam. This is attributed to suspended sediment in the inflowing Missouri River settling out in the reservoir as current velocities slow. The surface waters near Oahe Dam are significantly clearer than the upstream regions of the reservoir. Under the conditions that were monitored during the 5-year 2006 to 2010 period, it appears that sites OAHLK1256DW and OAHLK1196DW were in the riverine zone; site OAHLK1153DW was in the transition zone; site OAHLK1110DW was in the boundary area between the transition and lacustrine zones, and possibly impacted by the inflow of the Cheyenne River; and site OAHLK1073A was in the lacustrine zone of the reservoir.

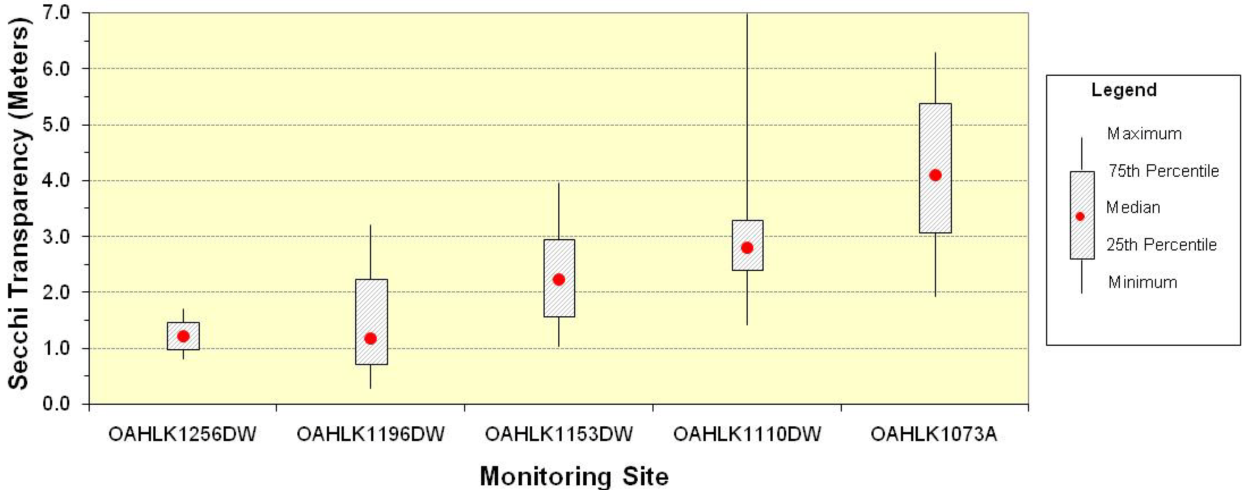


Figure 5-13. Box plot of Secchi transparencies measured in Lake Oahe during the 5-year period 2006 through 2010.
Note: Secchi transparencies at OAHLK1256DW are for 2009 and 2010 only.

5.4.2.1.5.2 Turbidity

Monthly (i.e., May, June, July, August, and September) longitudinal contour plots were prepared from the depth-profile turbidity measurements taken at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 during 2010 (Plate 177, Plate 178, Plate 179, Plate 180, and Plate 181). As seen in the contour plots, turbidity levels in Lake Oahe did not vary much throughout the reservoir in 2010. This is unlike recent years where turbidity varied longitudinally from the dam (less turbid) to the reservoir's upstream reaches (more turbid).

5.4.2.1.6 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Lake Oahe during the summer were compared. Near-surface conditions were represented by samples collected within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 1-meters of the reservoir bottom. The compared samples were collected at the near-dam site OAHLK1073A during the 5-year period 2006 through 2010. During the period a total of 18 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Plate 182). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different (α = 0.05). The sampled near-surface and near-bottom conditions were significantly different for water temperature, ORP, pH, and alkalinity. Parameters that were significantly lower in the near-bottom water of Lake Oahe included: water temperature ($p < 0.001$), and pH ($p < 0.001$). Parameters that were significantly higher in the near-bottom water included: ORP ($p < 0.001$) and alkalinity ($p < 0.05$).

5.4.2.1.7 Reservoir Trophic Status

Trophic State Index (TSI) values for Lake Oahe were calculated from monitoring data collected during the 5-year period 2006 through 2010 (Table 5-12). The calculated TSI values indicate that the lacustrine zone of the reservoir (i.e., sites OAHLK1073A and OAHLK1110DW) is mesotrophic, the transition zone (i.e., site OAHLK1153DW) is moderately eutrophic, and the riverine zone (i.e., sites OAHLK11961DW and OAHLK1256DW) is moderately eutrophic to eutrophic.

Table 5-12. Mean Trophic State Index (TSI) values calculated for Lake Oahe. TSI values are based on monitoring conducted at the identified five sites during 5-year period 2006 through 2010.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
OAHLK1073A	41	50	51	47
OAHLK1110DW	45	52	52	50
OAHLK1153DW	49	54	55	53
OAHLK1196DW	58	54	59	57
OAHLK1256DW*	57	51	56	54

Note: See Section 4.1.4 for discussion of TSI calculation.
* Based on monitoring conducted in 2009 and 2010 only.

5.4.2.1.8 Plankton Community

5.4.2.1.8.1 Phytoplankton

Phytoplankton grab samples were collected from Lake Oahe at five sites (i.e., OAHLK10730A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, and OAHLK1256DW) during the spring and summer of the 5-year period 2006 through 2010 (Plate 183, Plate 184, Plate 185, Plate 186, and Plate 187). Taxa identified in the collected phytoplankton samples were from seven taxonomic divisions: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The relative abundance of phytoplankton, based on biovolume, in samples collected from Lake Oahe in May, July, and September 2010 is shown in Figure 5-14. Diatoms (Bacillariophyta) are by far the most dominant phytoplankton group present in Lake Oahe. Major phytoplankton genera sampled in Lake Oahe during 2010 (i.e., genera comprising more than 10% of the total biovolume of at least one sample) included the Bacillariophyta *Asterionella*, *Aulacoseria*, *Fragilaria*, *Stephanodiscus*, and *Tabellaria*; Cryptophyta *Cryptomonas* and *Rhodomonas*; and Cyanobacteria *Aphanizomenon*. No concentrations of the cyanobacteria toxin microcystin above 1 ug/l were monitored in the lake during the 5-year period 2006 through 2010 (Plate 159, Plate 160, Plate 161, Plate 162, and Plate 163).

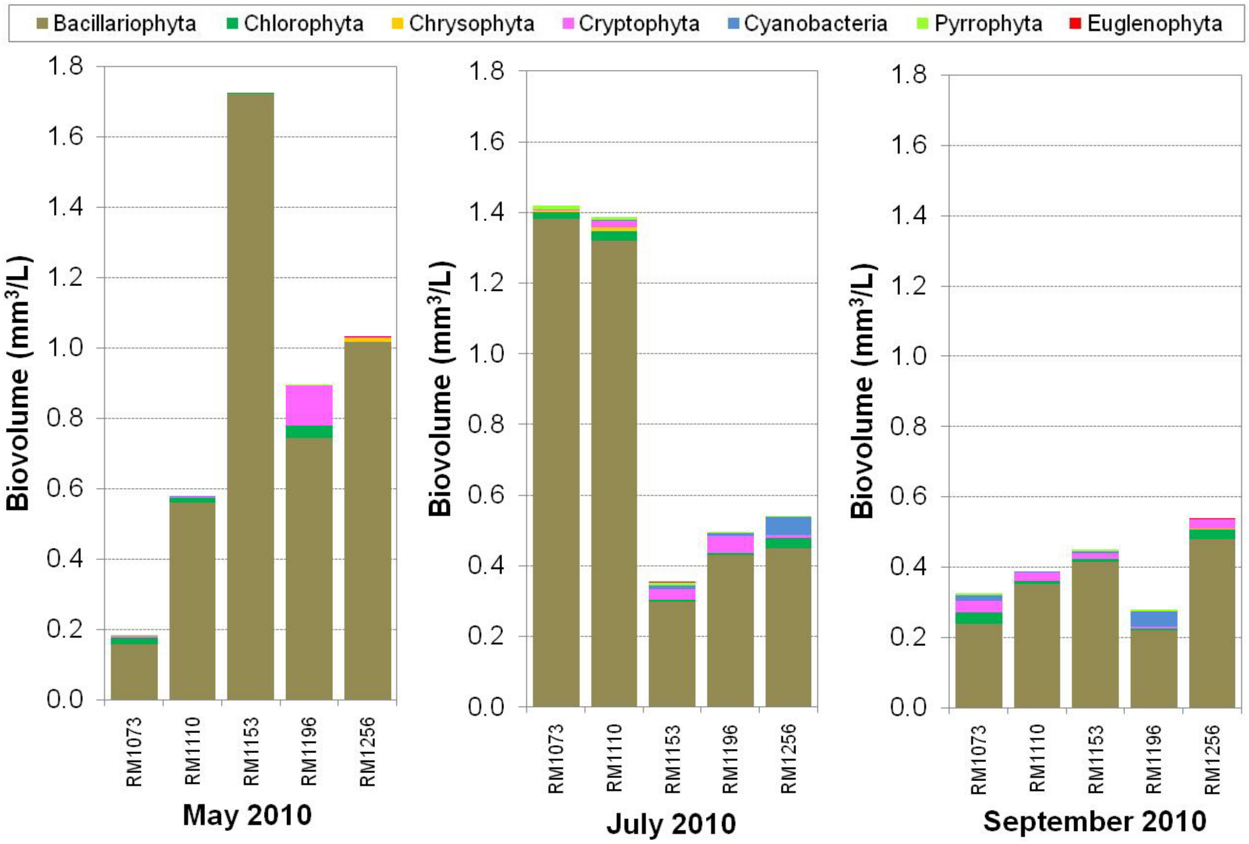


Figure 5-14. Relative abundance of phytoplankton in samples collected from Lake Oahe during 2010.

5.4.2.1.8.2 Zooplankton

Zooplankton vertical-tow samples were collected from Lake Oahe at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, and OAHLK1256DW in May, July, and September of 2010 (Plate 188). The sampled zooplankton included four taxonomic groupings: Cladocerans, Copepods, Rotifers, and Ostracods. The relative abundance of these four taxonomic grouping in the zooplankton samples collected in 2010 is shown in Figure 5-15. Cladocerans and copepods dominated the zooplankton community in Lake Oahe. Major zooplankton species sampled in Lake Oahe during 2010 (i.e., species comprising more than 10% of the total biomass of at least one sample) included Cladocerans *Daphnia pulex*, *Daphnia retrocurva*, and *Diaphanosoma brachyurum*; Copepods *Acanthocyclops vernalis*, *Calanoid copepodid*, *Cyclopoid copepodid*, *Diacyclops*, *thomasi*, *Leptodiaptomus ashlandi*, and *Mesocyclops edax*; and Rotifers *Asplanchna spp.*, *Keratella quadrata*, *Polyarthra major*, and *Polyarthra vulgaris.* Dominant species (i.e., species comprising more than 25% of the total biomass of at least one sample) included Cladocerans *Daphnia pulex*, *Daphnia retrocurva*; and Copepods *Cyclopoid copepodid*, *Diacyclops thomasi*, and *Mesocyclops edax.*

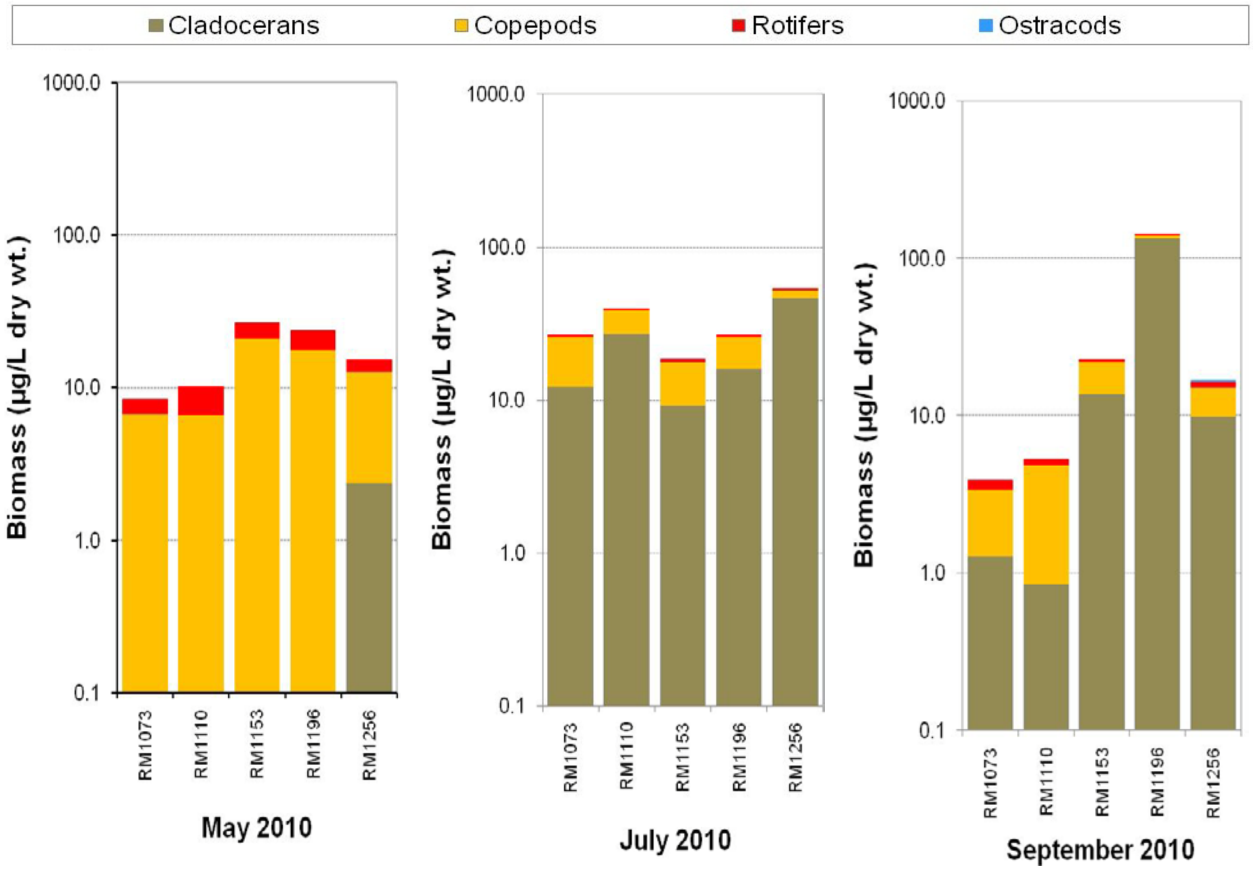


Figure 5-15. Relative abundance of zooplankton in samples collected from Lake Oahe during 2010**.**
Note: Y-axis is logarithmic scaled.

5.4.2.1.9 Impairment of Designated Water Quality Beneficial Uses

Based on the State of South Dakota's impairment assessment methodology (Section 4.1.6.4), the water quality conditions monitored in Lake Oahe during the 5-year period 2006 through 2010 did not indicate any impairment of designated water quality beneficial uses.

5.4.2.2 Water Quality Trends (1980 through 2010)

Water quality trends over the 31-year period of 1980 through 2010 were determined for Lake Oahe for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through September at the near-dam, ambient monitoring site (i.e., site OAHLK1073A). Plate 189 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., α = 0.05). For the assessment period, no significant trends were detected for Secchi depth, total phosphorus, or chlorophyll *a*. However, an increasing trend was detected for TSI ($p < 0.001$). Over the 31-year period, the reservoir has generally remained in a mesotrophic state.

5.4.3 EXISTING WATER QUALITY CONDITIONS OF THE MISSOURI RIVER INFLOW TO LAKE OAHE

5.4.3.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions that were monitored in the Missouri River at Bismarck, ND (i.e., site OAFNFMORR1) during the 5-year period 2006 through 2010 are summarized in Plate 190 and Plate 191. A review of these results indicated no major water quality concerns.

5.4.3.2 Vertical Water Quality Variation in the Missouri River

Depth discrete water quality monitoring of the Missouri River at site OAHNFMORR1 was initiated in 2010. Depth-profiles in ½-meter increments were measured for water temperature, dissolved oxygen, pH, conductivity, ORP, turbidity, and chlorophyll *a*. Near-surface and near-bottom grab samples were collected from the thalweg of the river at site OAHNFMORR1. The near-surface sample was collected by dipping a plastic churn bucket just below the water surface. The near-bottom sample was collected by lowering a finned-Van Dorn sampler to within ½-meter of the river bottom while the boat was drifting in the current.

5.4.3.2.1 Depth-Profile Plots

Depth-profile plots were constructed for water temperature, dissolved oxygen, pH, conductivity, turbidity, and chlorophyll *a* (Plate 192). The depth-profile plots indicate minimal variation in the six parameters with depth. The plots do indicate appreciable differences for selected parameters between monitoring dates.

5.4.3.3 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected at site OAHNFMORR1 during 2010 were compared. Five paired samples (May, June, July, August, and September) were collected during 2010. Box plots were constructed to display the distribution of the paired near-surface and near-bottom samples for selected non-particulate-associated (i.e., water temperature, total dissolved solid, dissolved sulfate, and dissolved phosphorus) and particulate-associated (i.e., total phosphorus, total Kjeldahl nitrogen, total suspended solids, total suspended sediment, and total organic carbon) constituents (Plate 193). Anecdotally, the box plots indicate no significant depth variation in the non-particulate-associated constituents. The box plots of the particulate-associated constituents indicate the median and maximum values for all these constituents were associated with the bottom samples. A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were not found to be significantly different for any dissolved parameter. The sampled near-surface and near-bottom conditions were found to be significantly different for total phosphorus ($p < 0.01$), total suspended solids ($p < 0.05$), total suspended sediment ($p < 0.05$), and total organic carbon ($p < 0.01$). Total Kjeldahl Nitrogen was the only particulate-associated parameter where the sampled near-surface and near-bottom conditions were found to be not significantly different.

The near-surface and near-bottom concentrations of the particulate-associated constituents total phosphorus, total Kjeldahl nitrogen, total suspended solids, total suspended sediment, and total organic carbon measured at site OAHNFMORR1 were plotted against the flow of the Missouri River at the time of sampling (Plate 194). Near-bottom concentrations of the particulate-associated constituents were higher than the near-surface levels under all flow conditions. The sediment associated parameters (i.e., total phosphorus, total suspended solids, and total suspended sediment seemingly had the highest variation between the near-surface and near-bottom water quality conditions.

5.4.3.4 Missouri River Inflow Nutrient Flux Conditions

Nutrient flux rates for the Missouri River inflow to Lake Oahe over the 5-year period 2006 through 2010 were calculated based on near-surface water quality samples collected near Bismarck, ND (i.e. site OAHNFMORR1) and the instantaneous flow conditions at the time of sample collection (Table 5-13). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom (see previous discussion). Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) are likely higher nearer the river bottom, near-surface grab samples likely under estimate the "true" water-column composite concentration for these constituents. Thus, the flux rates given for total phosphorus and total organic carbon in Table 5-13 should be considered minimum estimates with the actual flux rates being somewhat higher. The maximum flux rates for all the constituents are believed to be attributed to higher nonpoint-source loadings during runoff conditions.

Table 5-13. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Bismarck, ND during April through September over the 5-year period 2006 through 2010.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	28	28	28	28	28	28	27
Mean	16,162	0.0113	0.1629	0.0282	0.0236	0.0052	1.3397
Median	15,250	n.d.	0.1509	0.0320	0.0159	n.d.	1.2233
Minimum	10,564	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	28,900	0.0530	0.5230	0.0632	0.1594	0.0179	2.3712

n.d. = Nondetectable.
Note: Nondetect values set to 0 for flux calculations.

5.4.3.5 Continuous Water Temperature Monitoring of the Missouri River at USGS Gage Site 06342500 at Bismarck, North Dakota

Through an agreement with the USGS, a water temperature monitoring probe was added to the USGS's gage (06342500) on the Missouri River near Bismarck, ND (i.e., site OAHNFMORR1). Beginning in 2005, water temperature measurements were recorded at the site. Plate 195, Plate 196, Plate 197, Plate 198, and Plate 199, respectively, plot mean daily water temperature and river discharge determined for 2006, 2007, 2008, 2009, and 2010.

5.4.4 WATER QUALITY AT THE OAHE POWERPLANT

5.4.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 200 and Plate 201 summarize the water quality conditions that were measured in samples collected from water discharged through Oahe Dam during 5-year period 2006 through 2010. A review of these results indicated possible water quality concerns regarding temperature for the support of Coldwater Permanent Fish Life Propagation and arsenic for the protection of human health.

5.4.4.2 Impairment of Designated Water Quality Beneficial Uses

Based on the State of South Dakota's impairment assessment methodology (Section 4.1.6.4), the water quality conditions monitored at the Oahe powerplant during the 5-year period 2006 through 2010 indicate impairment of the designated Coldwater Permanent Fish Life Propagation water quality beneficial use.

Twenty-three percent of the "grab sample" water temperature measurements taken on the water passed through Oahe Dam exceeded the Coldwater Permanent Fish Life Propagation temperature criterion of 18.3°C. The exceedances of the temperature criterion occurred during the summer. In the summer when Lake Oahe is thermally stratified, water temperatures in the epilimnion of the reservoir regularly exceed 18.3°C, while temperatures in the hypolimnion are less than 18.3°C. Water discharged through Oahe Dam for power production is withdrawn from Lake Oahe at elevation 1524 ft-NGVD29, approximately 114 feet above the reservoir bottom. Thus, water withdrawn from the reservoir in the summer, especially when pool elevations are lower due to drought conditions, can pull water down from the epilimnion. When water passed through Oahe Dam during the summer is withdrawn from the epilimnion of the reservoir, the temperature criterion of 18.3°C for the Missouri River and Big Bend Reservoir just downstream of the dam are likely to be exceeded when Lake Oahe is thermally stratified. During 2010, pool elevations were near to above normal and two samples (August and September) collected at the Oahe powerplant exceeded the 18.3°C temperature criterion. Continuous water temperatures monitored at the Oahe powerplant during the past 5 years are shown in the time-series plots in the following section of this report.

All of the four total arsenic samples collected over the past 5 years exceeded the 0.018 ug/l criterion identified for the protection of human health. This criterion is concerned with bioaccumulation in the food chain and possible human health concerns regarding fish consumption.

5.4.4.3 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Semiannual time-series plots for temperature, dissolved oxygen, and dam discharge monitored at the Oahe powerplant during the 5-year period 2006 through 2010 were constructed (Plate 202 - Plate 221). Water temperatures showed seasonal warming and cooling through each calendar year. Dissolved oxygen levels remained relatively high and stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall. The lowest dissolved oxygen levels occurred during the late-summer period. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. The decreasing dissolved oxygen in the July to September period may also be attributed somewhat to the influence of ongoing degradation of dissolved oxygen in the hypolimnion as the summer progressed. Overall, there appeared to be minor correlation between discharge rates and measured water temperature and dissolved oxygen concentrations. However, there appeared to be more correlation between discharge and water temperature in the summers of 2009 and 2010. In 2009 and 2010 pool levels returned to normal after several years of prolonged drought. This resulted in the summer thermocline in Lake Oahe setting up at a higher elevation; above the intake elevation of the power tunnels. This seemingly resulted in colder water being drawn from the hypolimnion under lower discharges, and warmer water being drawn down from the epilimnion under higher discharges. In the drought years of 2005 through 2007 and the drought recovery year of 2008, discharge water temperatures in the summer regularly exceeded the coldwater permanent fish life protection criterion of 18.3°C. With the higher pool elevations in 2009 and 2010, the overall water temperature of the Oahe Dam discharge was cooler during the summer and the 18.3°C criterion was exceeded less frequently.

5.4.4.4 Comparison of Monitored Inflow and Outflow Temperatures of the Missouri River at Lake Oahe

Plate 222, Plate 223, Plate 224, Plate 225, and Plate 226, respectively, plot the mean daily water temperatures monitored at the Missouri River near Bismarck, ND (site OAHNFMORR1) and the Oahe Dam powerplant (site OAHPP1) for 2006, 2007, 2008, 2009, and 2010. Inflow temperatures of the Missouri River to Lake Oahe are generally warmer than the outflow temperatures of Oahe Dam during the period of April through July. Outflow temperatures of the Oahe Dam discharge are generally warmer than the inflow temperatures of the Missouri River during the period of August through March. A maximum temperature difference occurs in the fall when the Oahe Dam outflow temperature is about 4-6°C warmer than the Missouri River inflow temperature.

5.4.4.5 Nutrient Flux Conditions of the Oahe Dam Discharge to the Missouri River

Nutrient flux rates for the Oahe Dam discharge to the Missouri River over the 5-year period 2009 through 2010 were calculated based on samples taken from the Oahe powerplant (i.e. site OAHPP1) and the dam discharge at the time of sample collection (Table 5-14). The samples collected in the powerplant are taken from the raw water supply line and are believed to be unbiased regarding particulate-associated constituents. Therefore, the flux rates calculated for the Oahe Dam discharge give an unbiased estimate of the flux rates for all the constituents, including total phosphorus and total organic carbon. The maximum flux rates for all the constituents are believed to be attributed to higher dam discharges.

Table 5-14. Summary of nutrient flux rates (kg/sec) calculated for the Oahe Dam discharge to the Missouri River (i.e., site OAHPP1) during January through December over the 5-year period 2006 through 2010.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	45	45	45	45	45	43	43
Mean	24,638	0.0190	0.2342	0.0382	0.0186	0.0092	2.3303
Median	23,062	n.d.	0.1845	n.d.	0.0168	n.d.	2.2084
Minimum	1,427	n.d.	n.d.	n.d.	n.d.	n.d.	0.1010
Maximum	56,047	0.1249	1.0239	0.1902	0.0759	0.0448	7.4590

Note: Nondetectable values set to 0 for flux calculations.

5.5 BIG BEND

5.5.1 BACKGROUND INFORMATION

5.5.1.1 Project Overview

Big Bend Dam is located in central South Dakota on the Missouri River at RM 987.4, 21 miles northwest of Chamberlain, SD. The closing of Big Bend Dam in 1963 resulted in the formation of Big Bend Reservoir (Lake Sharpe). The reservoir, when full, is 80 miles long, covers 61,000 acres, and has 200 miles of shoreline. Table 5-15 summarizes how the surface area, volume, mean depth, and retention time of Lake Sharpe vary with pool elevations. The Big Bend powerplant is operated to meet peak power demands for electricity. Generally, weekly flows from Oahe Dam are released at Big Bend Dam, and there is minimal fluctuation in the water level of Lake Sharpe. The Annual Flood Control and Multiple Use Zone in the reservoir does not provide for seasonal regulation of flood inflows like the other major

upstream Mainstem System Projects, but the zone is used for day-to-day and week-to-week power operations. The Corps normally strives to maintain the pool level in the reservoir between elevation 1419 and 1421.5 ft-NGVD29. There are no minimum flow requirements below Big Bend Dam, and hourly releases can fluctuate from 0 to 110,000 cfs for peaking power generation. The major inflows to Lake Sharpe are the Missouri River and Bad River. Water discharged through Big Bend Dam for power production is withdrawn from the bottom of Lake Sharpe at an invert elevation of 1330.0 ft-NGVD29. Figure 5-16 shows a diagrammatic view of the Big Bend Dam area and a photo of the Big Bend Dam powerplant intake structure during construction prior to inundation.

Table 5-15. Surface area, volume, mean depth, and retention time of Lake Sharpe at different pool elevations based on 1997 bathymetric survey.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1430	70,615	2,259,568	32.0	0.1344
1425	63,808	1,923,508	30.1	0.1144
1420	57,007	1,621,484	28.4	0.0965
1415	50,224	1,353,339	26.9	0.0805
1410	43,146	1,119,548	25.9	0.0666
1405	35,694	923,872	25.9	0.0550
1400	31,842	756,297	23.8	0.0450
1395	27,402	608,587	22.2	0.0362
1390	24,659	479,172	19.4	0.0285
1385	21,779	362,729	16.7	0.0216
1380	18,307	262,285	14.3	0.0156
1375	14,856	179,548	12.1	0.0107
1370	11,747	113,160	9.6	0.0067
1365	8,590	62,333	7.3	0.0037
1360	5,449	27,069	5.0	0.0016
1355	2,021	9,373	4.6	0.0006
1350	836	2,445	2.9	0.0001

Average Annual Inflow (1967 through 2010) = 16.98 Million Acre-Feet.
Average Annual Outflow: (1967 through 2010) = 16.81 Million Acre-Feet.
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1423-1422 ft-NGVD29), Annual Flood Control and Multiple Use Zone (elev. 1422-1420 ft-NGVD29), Carryover Multiple Use Zone (none), and Permanent Pool Zone (elev. 1420-1345 ft-NGVD29). All elevations are in the NGVD 29 datum.

The reservoir and dam are authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. Over the period 1967 through 2010, the eight generating units at Big Bend Dam produced an annual average 0.969 million MWh of electricity. Past drought conditions in the interior western United States has curtailed releases and power production at the Missouri River mainstem system projects, including Big Bend. Power production at the Big Bend Dam generating units averaged an annual 0.654 million MWh over the 5-year period 2006 through 2010. Habitat for one endangered species, interior least tern, and one threatened species, piping plover, occurs within the project area. Three surface water intakes are located in Lake Sharpe: Mni Wiconi Rural Water System (RM1070 – 12 counties and Lower Brule, Rosebud, and Pine Ridge Indian Reservations); Lower Brule Rural Water System (RM993 – Lower Brule); and Fort Thompson Rural Water Service (RM987 – Fort Thompson). The reservoir is an important recreational resource.

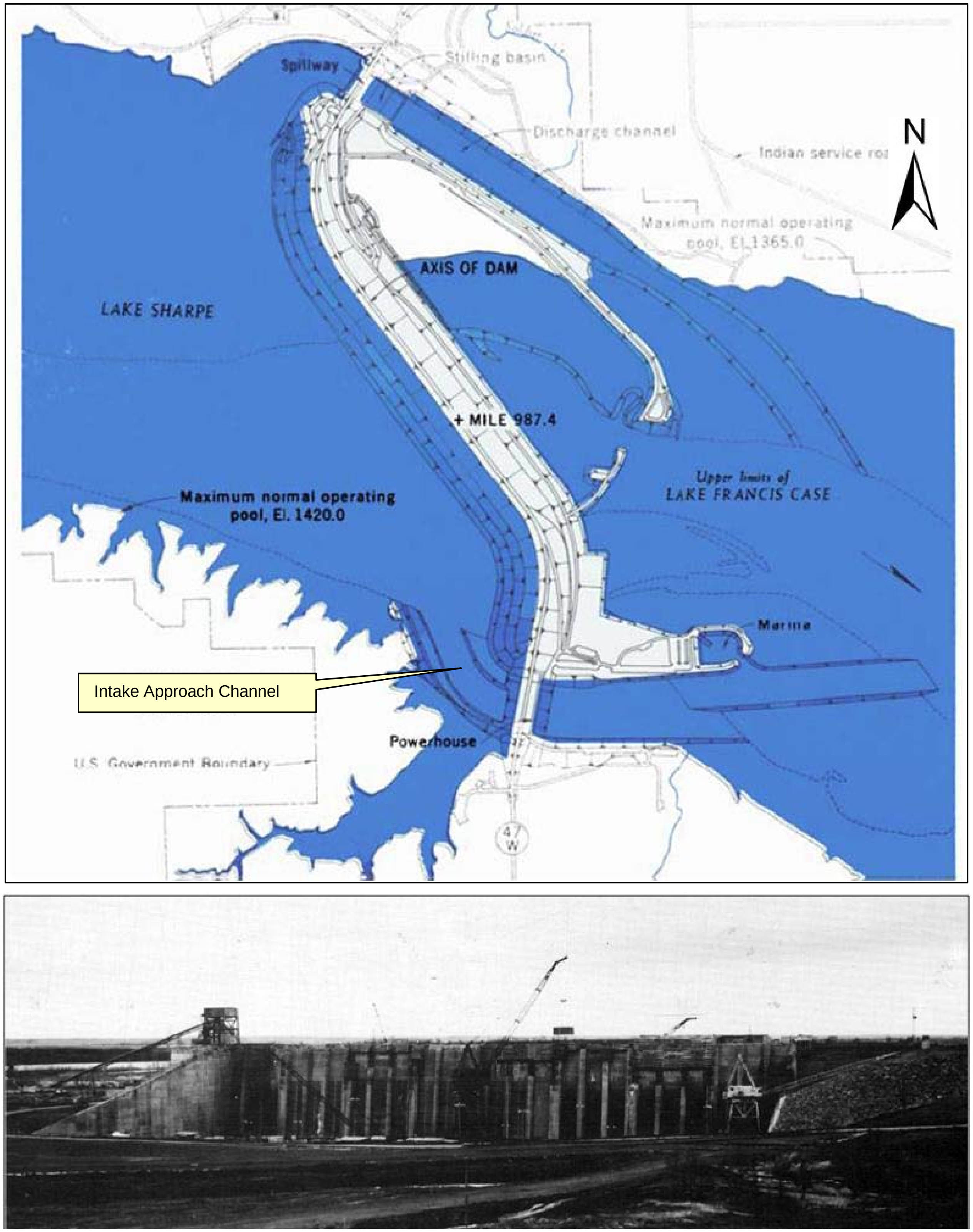


Figure 5-16. Diagrammatic view of Big Bend Dam area and photo of the Big Bend powerplant intake structure in final stages of construction prior to inundation.

5.5.1.2 Water Quality Standards Classification and Section 303(d) Listings

5.5.1.2.1 Lake Sharpe

South Dakota has classified the Missouri River impoundments within the State as flowing streams and not reservoirs (South Dakota Administrative Rules 74:51:01:43). The following water quality-dependent beneficial uses have been designated for Lake Sharpe in South Dakota's water quality standards: domestic water supply waters, coldwater permanent fish life propagation waters, immersion recreation waters, limited-contact recreation waters, commerce and industry waters, agricultural water supply (i.e., irrigation and stock watering), and fish and wildlife propagation. The State of South Dakota added Lake Sharpe to the State's 2010 Section 303(d) list of impaired waters. The reservoir use identified as impaired is coldwater permanent fish life propagation waters and the cause of impairment is identified as warm water temperatures. South Dakota is currently pursuing reclassification of Lake Sharpe from a coldwater fishery to a warmwater fishery based on a use attainability assessment of "natural conditions". Summer water temperatures discharged from Oahe Dam, especially during lower pool levels, don't meet the temperature criteria for a coldwater fishery use. South Dakota had recently delisted Lake Sharpe for Section 303(d) impairment due to sedimentation. The reservoir was previously listed as water quality impaired due to accumulated sediment from the Bad River watershed. A total maximum daily load (TMDL) was developed and is being implemented to address this concern, resulting in the delisting of Lake Sharpe for sedimentation. South Dakota has not issued a fish consumption advisory for the reservoir.

5.5.1.2.2 Missouri River Downstream of Big Bend Dam

The State of South Dakota has designated the following water quality-dependent beneficial uses for the Missouri River downstream of Big Bend Dam: domestic water supply waters, warmwater permanent fish life propagation waters, immersion recreation waters, limited-contact recreation waters, commerce and industry waters, agricultural water supply (i.e., irrigation and stock watering), and fish and wildlife propagation. Big Bend Dam is the current demarcation point between coldwater and warmwater use designation on the Missouri River system in South Dakota. Therefore, the designated use of Warmwater Permanent Fish Life Propagation applies to the Big Bend Dam tailwaters instead of the Coldwater Permanent Fish Life Propagation use that applies to Lake Sharpe. South Dakota has not issued a fish consumption advisory for the Missouri River downstream of Big Bend Dam.

5.5.1.2.3 Ambient Water Quality Monitoring

The District has monitored water quality conditions at the Big Bend Project since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow to and outflow from the reservoir. A 3-year intensive water quality survey was completed in 2010 and the findings of the intensive survey are available in the separate report, "Water Quality Conditions Monitored at the Corps' Big Bend Project in South Dakota during the 3-Year period 2008 through 2010" (USACE, 2011b). The water quality conditions of the Oahe Dam discharge are taken to represent the inflow water quality conditions of the Missouri River to Lake Sharpe. Figure 5-17 shows the location of sites at the Big Bend Project that have been monitored for water quality during the past 5 years (i.e., 2006 through 2010). The near-dam location (i.e., site BBDLK0987A) has been continuously monitored since 1980.

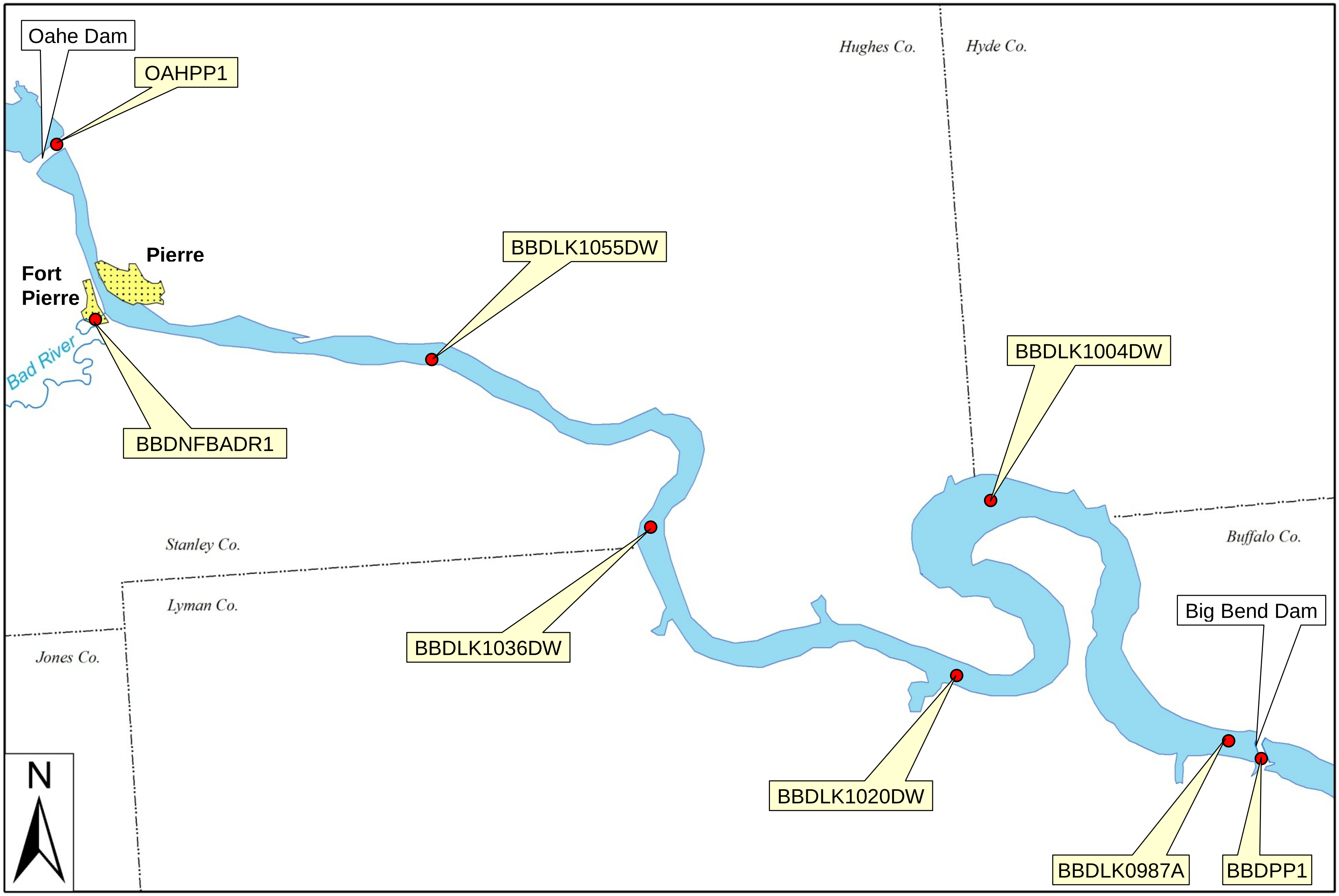


Figure 5-17. Location of sites where water quality monitoring was conducted by the District at the Big Bend Project during the 5-year period 2006 through 2010.

5.5.2 WATER QUALITY IN LAKE SHARPE

5.5.2.1 Existing Water Quality Conditions

5.5.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Water quality conditions that were monitored in Lake Sharpe at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, and BBDLK1055DW from May through September during the 5-year period 2006 through 2010 are summarized in Plate 227, Plate 228, Plate 229, Plate 230, and Plate 231. A review of these results indicated water quality concerns regarding water temperature and dissolved oxygen for the support of Coldwater Permanent Fish Life Propagation (CPFLP). Due to its shallowness, a hypolimnion rarely forms in Lake Sharpe and water temperatures throughout the reservoir regularly exceed 18.3°C in the summer. Dissolved oxygen levels near the bottom of the reservoir occasionally fall below the 6.0 mg/l CPFLP criterion during the summer. The lowest dissolved oxygen concentration measured during the 5-year period at the five sites was 3.2 mg/l, and occurred near the dam at site BBDLK0987A in August 2008. The suspended solids criteria for the protection of CPFLP are regularly exceeded in the upper end of Lake Sharpe (Plate 231). This is attributed to finer sediment that has been deposited in Lake Sharpe below the confluence of the Bad River and its continual resuspension with wave action.

5.5.2.1.2 Summer Thermal Stratification

5.5.2.1.2.1 Monthly Longitudinal Temperature Contour Plots

Summer thermal stratification of Lake Sharpe during 2010 is described by the monthly longitudinal temperature contour plots based on depth-profile temperature measurements taken in June, July, August, and September (Plate 232, Plate 233, Plate 234, and Plate 235). The contour plots were constructed along the length of the reservoir. As seen in the contour plots, water temperature in Big Reservoir varies longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Cooler water is typically discharged from Oahe Dam from late-spring through mid-summer which quickly warms in Lake Sharpe. Although some summer thermal stratification of Lake Sharpe can occur, the relative shallowness, short retention time, and bottom withdrawal of the reservoir seemingly inhibit the formation of a strong thermocline and long-lasting thermal stratification during the summer.

5.5.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Lake Sharpe at the deep water area near the dam is described by the depth-profile temperature plots measured over the 5-year period 2006 through 2010. Depth-profile temperature plots measured during the summer months were compiled (Plate 236). No significant temperature-depth gradient is apparent in Lake Sharpe in the near-dam area during the summer.

5.5.2.1.3 Summer Dissolved Oxygen Conditions

5.5.2.1.3.1 Monthly Longitudinal Dissolved Oxygen Contour Plots

Dissolved oxygen longitudinal contour plots were constructed along the length of Lake Sharpe based on depth-profile measurements taken in June, July, August, and September of 2010 (Plate 237, Plate 238, Plate 239, and Plate 240). During the summer of 2010, dissolved oxygen conditions in Lake Sharpe varied longitudinally from the dam to the reservoir's upstream reaches and vertically from the

reservoir surface to the bottom. Dissolved oxygen levels below 6 mg/l were monitored in July and August at the reservoir bottom near the dam.

5.5.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Existing summer dissolved oxygen conditions in Lake Sharpe at the deep-water area near the dam are described by the depth-profile dissolved oxygen plots measured over the 5-year period 2006 through 2010. Depth-profile dissolved oxygen plots measured during the summer months at site BBDLK0987A were compiled (Plate 241). Dissolved oxygen levels below 6 mg/l regularly occurred near the bottom of the reservoir, and levels near the reservoir bottom approached 3 mg/l on three occasions.

5.5.2.1.4 Occurrence of Coldwater Permanent Fish Life Propagation Habitat in Lake Sharpe

The most crucial period for the support of Coldwater Permanent Fish Life Propagation (CPFLP) habitat in Lake Sharpe is during mid-summer. Monitoring indicates that the reservoir is probably discontinuous polymictic with a hypolimnion only forming on an irregular basis. This results in complete mixing and warming of the water column above 18.3°C during the summer. When stratification does persist, dissolved oxygen degradation to levels below 6 mg/l occurs near the reservoir bottom in deeper waters near the dam.

The occurrence of CPFLP habitat (i.e., water temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l) in Lake Sharpe was estimated from collected water temperature and dissolved oxygen depth-profile measurements. Conditions supportive of CPFLP were present in 40, 14, 33, 57, and 62 percent of the depth-profile measurements respectively taken at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, and BBDLK1055DW during the 5-year period 2006 through 2010 (Plate 227 - Plate 231). Conditions supportive of CPFLP are rarely present anywhere in the reservoir during the months of July and August. Ambient water temperatures in Lake Sharpe do not appear to be cold enough to support CPFLP, as defined by State water quality criteria, during mid-summer. Consideration should be given to reclassify the reservoir for a Warmwater Permanent Fish Life Propagation use based on a use attainability assessment of "natural conditions" regarding ambient water temperatures.

5.5.2.1.5 Water Clarity

5.5.2.1.5.1 Secchi Transparency

Figure 5-18 displays a box plot of the Secchi depth transparencies measured along Lake Sharpe at the five sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW, and Oahe Dam tailwaters during the 3-year period 2008 through 2010. The Secchi depth of the Oahe Dam tailwaters was taken to be the Secchi depth measured in Lake Oahe at the near-dam monitoring site (i.e., OAHLK1073A). Secchi depth transparency decreased significantly in the upstream reaches of Lake Sharpe. This pronounced decrease in transparency is attributed to turbid runoff from the Bad River and sedimentation in the upstream reaches of the reservoir attributed to the Bad River. The "light" nature of these sediments and the shallowness of Lake Sharpe in its upstream reaches allows for wind action to continually re-suspend deposited sediment in this area of the reservoir.

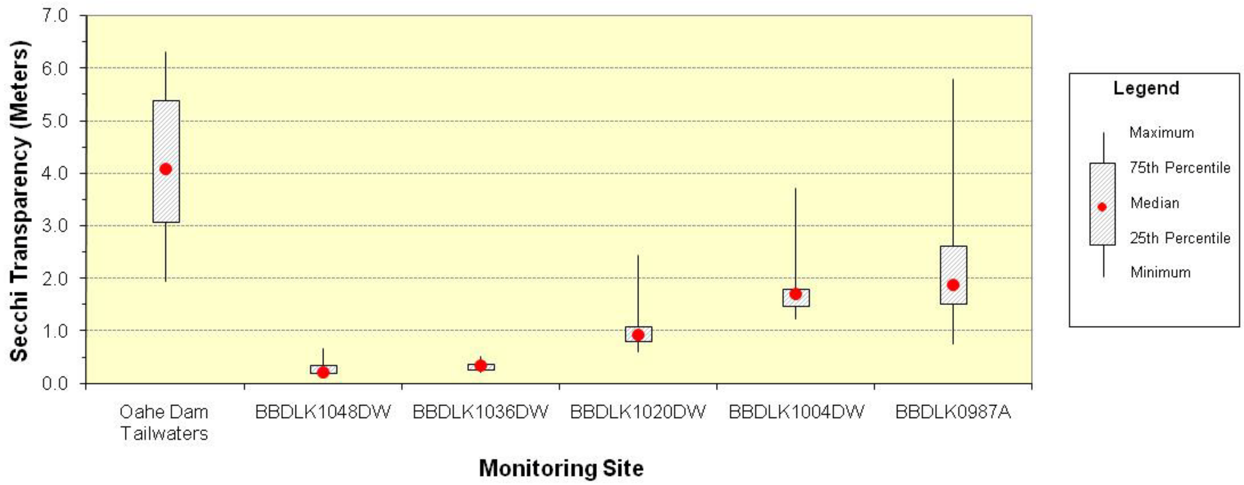


Figure 5-18. Box plot of Secchi transparencies measured in Lake Sharpe during the 3-year period 2008 through 2010.

5.5.2.1.5.2 Turbidity

Monthly (i.e., June, July, August, and September) longitudinal contour plots were prepared from the depth-profile turbidity measurements taken at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW, and OAHPP1 during 2010 (Plate 242, Plate 243, Plate 244, and Plate 245). As seen in the contour plots, turbidity levels measured in Lake Sharpe during 2010 varied longitudinally from the dam to the reservoir's upstream reaches; especially in June (Plate 242). The Bad River inflow and sedimentation delta seemingly have a pronounced impact on turbidity in the upstream reaches of Lake Sharpe.

5.5.2.1.6 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Lake Sharpe during the summer were compared. Near-surface conditions were represented by samples collected within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 1-meter of the reservoir bottom. The compared samples were collected at the near-dam site BBDLK0987A during the 5-year period 2006 through 2010. During the period a total of 20 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Plate 246). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different (α = 0.05). The sampled near-surface and near-bottom conditions were significantly different for water temperature, dissolved oxygen, ORP, pH, TKN, and total ammonia. Parameters that were significantly lower in the near-bottom water of Lake Sharpe included: water temperature ($p < 0.001$), dissolved oxygen ($p < 0.001$), and pH ($p < 0.01$). Parameters that were significantly higher in the near-bottom water included: ORP ($p < 0.001$), TKN ($p < 0.05$), and total ammonia ($p < 0.05$).

5.5.2.1.7 Reservoir Trophic Status

Trophic State Index (TSI) values for Lake Sharpe were calculated from monitoring data collected during the 3-year period 2008 through 2010 (Table 5-16). The calculated TSI values indicate that the area

near the dam (i.e., site BBDLK0987A) is mesotrophic to moderately eutrophic, the middle reach of the reservoir (i.e., site BBDLK1020DW) is eutrophic, and the upstream reach of the reservoir (i.e., site BBDLK1055DW) is eutrophic to borderline hypereutrophic. However, it is noted that the calculated average TSI value for the upstream reaches is greatly influenced by the low water clarity in this part of the reservoir. This lack of water clarity is largely attributed to suspended inorganic material delivered to the reservoir by the Bad River. Thus, the higher TSI values in the upstream reaches may not be indicative of increased algal growth associated with nutrient enrichment.

Table 5-16. Mean Trophic State Index (TSI) values calculated for Lake Sharpe. TSI values are based on monitoring at the identified three sites during the 3-year period 2008 through 2010.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
BBDLK0987A	47	49	54	50
BBDLK1020DW	60	53	60	58
BBDLK1055DW	79	60	56	65

Note: See Section 4.1.4 for discussion of TSI calculation.

5.5.2.1.8 Plankton Community

5.5.2.1.8.1 Phytoplankton

Phytoplankton grab samples collected from Lake Sharpe at sites BBDLK0987A, BBDLK1020DW, and BBDLK1055DW during the spring and summer over the 3-year period 2008 through 2010 are summarized in Plate 247, Plate 248, and Plate 249. The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The relative abundance of phytoplankton in samples collected from Lake Sharpe in May, July, and September 2010, based on biovolume, is shown in Figure 5-19. Diatoms (Bacillariophyta) are by far the most dominant phytoplankton group present in Lake Sharpe. Major phytoplankton genera sampled in Lake Sharpe during 2010 (i.e., genera comprising more than 10% of the total biovolume of at least one sample) included the Bacillariophyta *Asterionella*, *Aulacoseria, Fragilaria, Navicula, Surirella, Synedra,* and *Tabellaria*. No concentrations of the cyanobacteria toxin microcystin above 1 ug/l were monitored in the lake during the 5-year period 2006 through 2010 (Plate 227, Plate 229, and Plate 231).

5.5.2.1.8.2 Zooplankton

Zooplankton vertical-tow samples were collected from Lake Sharpe at sites BBDLK0987A, BBDLK1020DW, and BBDLK1055DW in May, July, and September of 2010 (Plate 250). The sampled zooplankton included three taxonomic groupings: Cladocerans, Copepods, and Rotifers. The relative abundance of these three taxonomic grouping in the zooplankton samples collected in 2010 is shown in Figure 5-20. Cladocerans and copepods dominated the zooplankton community in Lake Sharpe. Major zooplankton species sampled in Lake Sharpe during 2010 (i.e., species comprising more than 10% of the total biomass of at least one sample) included Cladocerans *Bosmina longirostris, Daphnia retrocurva,* and *Eubosmina coregoni*; Copepods *Calanoid copepodid, Cyclopoid copepodid, Diacyclops, thomasi,* and *Mesocyclops edax*; and Rotifers *Polyarthra major,* and *Synchaeta pectinata.* Dominant species (i.e., species comprising more than 25% of the total biomass of at least one sample) included Cladocerans *Daphnia retrocurva*; Copepods *Calanoid copepodid, Cyclopoid copepodid, Diacyclops thomasi,* and *Mesocyclops edax*, and Rotifers *Polyarthra major.*

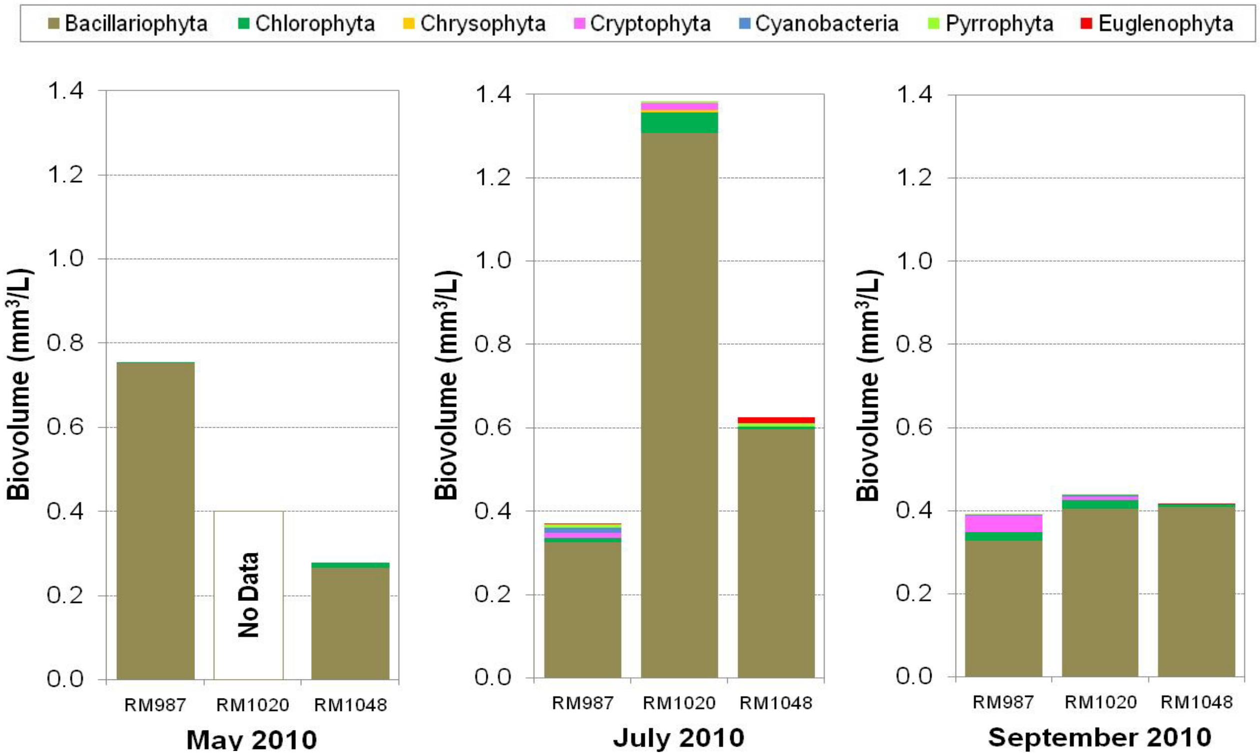


Figure 5-19. Relative abundance of phytoplankton in samples collected from Lake Sharpe during 2010.

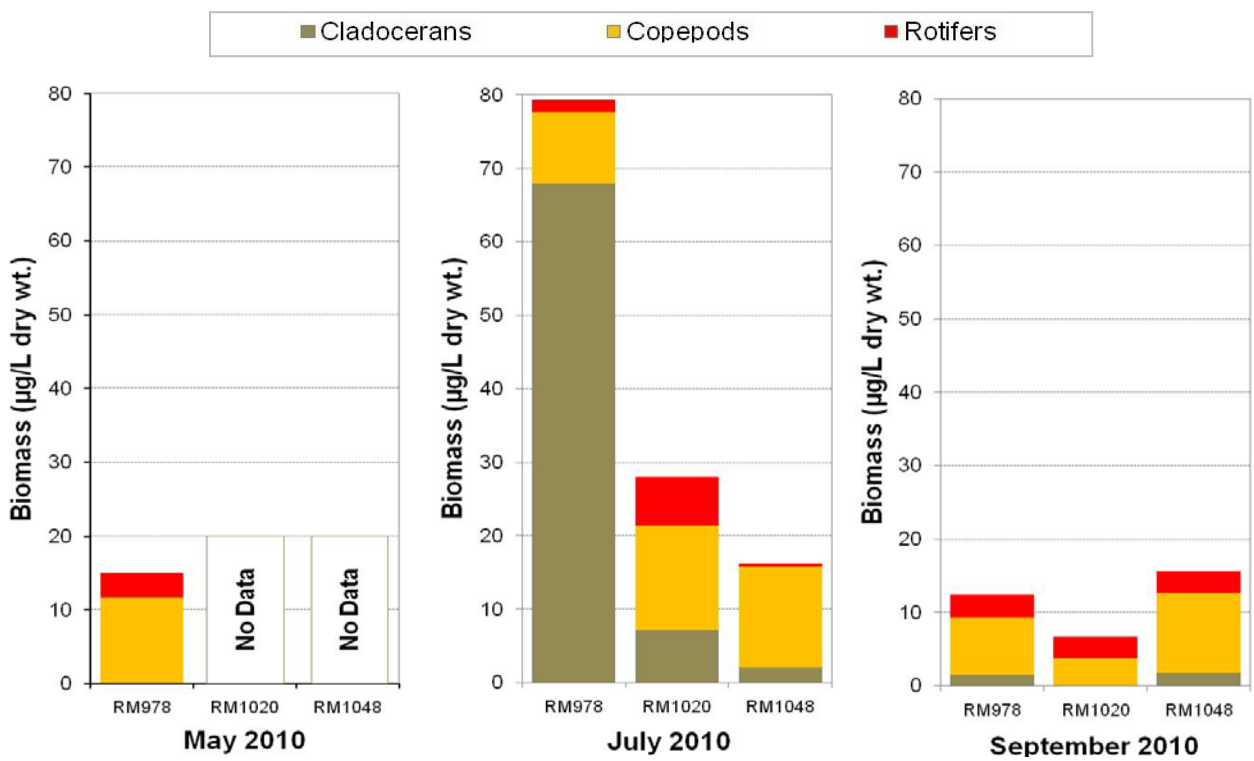


Figure 5-20. Relative abundance of zooplankton in samples collected from Lake Sharpe during 2010**.**

5.5.2.1.9 Impairment of Designated Water Quality Beneficial Uses

Based on the State of South Dakota's impairment assessment methodology (Section 4.1.6.4), the water quality conditions monitored in Lake Sharpe during the 5-year period 2006 through 2010 indicate that the designated Coldwater Permanent Fish Life Propagation use is not being attained due to warm water temperatures. Consideration should be given to reclassify the reservoir for a Warmwater Permanent Fish Life Propagation use based on a use attainability assessment of "natural conditions" regarding ambient water temperatures.

5.5.2.2 Water Quality Trends (1980 through 2010)

Water quality trends over the 31-year period of 1980 through 2010 were determined for Lake Sharpe for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam, ambient monitoring site (i.e., site BBDLK0987A). Plate 251 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, Lake Sharpe exhibited significant trends for Secchi depth (decreasing) and TSI (increasing). No significant trend was detected for total phosphorus and chlorophyll *a*. Over the 31-year period, the reservoir has generally remained mesotrophic to moderately eutrophic.

5.5.3 EXISTING WATER QUALITY CONDITIONS OF THE MISSOURI AND BAD RIVER INFLOWS TO LAKE SHARPE

5.5.3.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions of the Missouri River inflow to Lake Sharpe is taken to be the monitored water quality conditions of the outflow from Oahe Dam. See Plate 200 and Plate 201 for a summary of the water quality conditions monitored on the water discharged from Oahe Dam. The water quality conditions of the Bad River inflow to Lake Sharpe monitored at site BBDNFBADR1 during the 3-year period 2008 through 2010 are summarized in Plate 252.

5.5.3.2 Missouri River Inflow Nutrient Flux Conditions

Nutrient flux rates for the Missouri River inflow to Lake Sharpe over the last 5 years were calculated based on water quality conditions monitored on water discharged through the Oahe Dam powerplant (i.e. site OAHPP1) (Table 5-17). During this 5-year period, all water discharged at Oahe Dam was through the powerplant. The samples collected in the Oahe powerplant are taken from the raw water supply line and are believed to be unbiased regarding particulate-associated constituents. Therefore, the flux rates calculated for the Oahe Dam discharge give an unbiased estimate of the flux rates for all the constituents, including total phosphorus and total organic carbon. The maximum flux rates for all the constituents are believed to be attributed to higher dam discharges.

Table 5-17. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Oahe Dam (i.e., site OAHPP1) over the 5-year period 2006 through 2010.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	45	45	45	45	45	43	43
Mean	24,638	0.0190	0.2342	0.0382	0.0186	0.0092	2.3303
Median	23,062	n.d.	0.1845	n.d.	0.0168	n.d.	2.2084
Minimum	1,427	n.d.	n.d.	n.d.	n.d.	n.d.	0.1010
Maximum	56,047	0.1249	1.0239	0.1902	0.0759	0.0448	7.4590

n.d. = Nondetectable.
Note: Nondetect values set to 0 for flux calculations.

5.5.3.3 Mean Daily Discharge and Temperature

Mean daily discharge and water temperature of the Oahe Dam outflow was determined for the past 5 years. These are considered the water quality conditions of the Missouri River inflow to Lake Sharpe. Plate 253, Plate 254, Plate 255, Plate 256, and Plate 257, respectively, plot 2006, 2007, 2008, 2009, and 2010 mean daily water temperature and flow for the Oahe Dam discharge.

5.5.4 WATER QUALITY AT THE BIG BEND DAM POWERPLANT

5.5.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 258 and Plate 259 summarize the water quality conditions that were monitored on water discharged through Big Bend Dam during the 5-year period 2006 through 2010. A review of these results seemingly found no significant water quality concerns. However, the 0.18 ug/l human health criterion for total arsenic was exceeded on all four occasions. The highest total arsenic concentration measured was 2 ug/l.

5.5.4.2 Impairment of Designated Water Quality Beneficial Uses

Based on the State of South Dakota’s impairment assessment methodology (Section 4.1.6.4), the water quality conditions monitored at the Big Bend powerplant during the 5-year period 2006 through 2010 did not indicate any impairment of designated water quality beneficial uses.

5.5.4.3 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Semiannual time-series for temperature, dissolved oxygen, and dam discharge monitored at the Big Bend powerplant during the 5-year period 2006 through 2010 were plotted (Plate 260 - Plate 279). Water temperatures showed seasonal warming and cooling through each calendar year. Dissolved oxygen levels remained relatively high and fairly stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall. The lowest dissolved oxygen levels occurred during the July to August period. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. There appeared to be significant correlation between discharge rates and water temperature and dissolved oxygen concentrations measured during the summer months. The lower dissolved oxygen concentrations monitored in the summer may be attributed to periodic stratification and the degradation of dissolved oxygen conditions near the bottom of the reservoir. Since the inlet to the powerhouse is located

at the reservoir bottom, lower flows through the dam may result in more "laminar" flow that pulls in water with degraded dissolved oxygen conditions along the bottom into the powerplant.

5.5.4.4 Comparison of Monitored Inflow and Outflow Temperatures of the Missouri River at Lake Sharpe

Plate 280, Plate 281, Plate 282, Plate 283, and Plate 284, respectively, plot the mean daily water temperatures monitored for the Missouri River at Oahe Dam (site OAHPP1) and the Big Bend Dam powerplant (site BBDPP1) for 2006, 2007, 2008, 2009, and 2010. Inflow temperatures of the Missouri River to Lake Sharpe are about 4°C warmer than the outflow temperatures of Big Bend Dam during the fall. Outflow temperatures of the Big Bend Dam discharge are about 5°C warmer than the inflow temperatures of the Missouri River during the spring, summer, and fall.

5.5.4.5 Nutrient Flux Conditions of the Big Bend Dam Discharge to the Missouri River

Nutrient flux rates for the Big Bend Dam discharge to the Missouri River over the 5-year period 2006 through 2010 were calculated based on samples taken from the Big Bend powerplant (i.e. site BBDPP1) and the dam discharge at the time of sample collection (Table 5-18). The samples collected in the powerplant are taken from the raw water supply line and are believed to be unbiased regarding particulate-associated constituents. Therefore, the flux rates calculated for the Big Bend Dam discharge give an unbiased estimate of the flux rates for all the constituents, including total phosphorus and total organic carbon. The maximum flux rates for all the constituents are believed to be attributed to higher dam discharges.

Table 5-18. Summary of nutrient flux rates (kg/sec) calculated for the Big Bend Dam discharge to the Missouri River (i.e., site BBDPP1) during January through December over the 5-year period 2006 through 2010.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	49	49	49	49	49	47	48
Mean	27,604	0.0281	0.4132	0.0687	0.0409	0.0128	2.7038
Median	23,801	n.d.	0.3294	n.d.	0.0169	n.d.	2.2949
Minimum	0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	71,717	0.1760	1.3553	1.7608	0.5848	0.1056	8.9799

Note: Nondetectable values set to 0 for flux calculations.

5.6 FORT RANDALL

5.6.1 BACKGROUND INFORMATION

5.6.1.1 Project Overview

Fort Randall Dam is located on the Missouri River at RM 880.0 in southeastern South Dakota, 50 miles southwest of Mitchell, SD. The closing of Fort Randall Dam in 1952 resulted in the formation of Fort Randall Reservoir (Lake Francis Case). When full, the reservoir is 107 miles long, covers 102,000 acres, and has 540 miles of shoreline. Table 5-19 summarizes how the surface area, volume, mean depth, and retention time of Lake Francis Case vary with pool elevations. The reservoir at the end of December

2010 was at pool elevation 1340.5 ft-NGVD29. This is 9.5 feet below the top of the Carryover Multiple Use Zone (1350.0 ft-NGVD29). A "low" pool level is typical for Lake Francis Case at the end of December because this reservoir is drawn down each fall to provide storage space for high winter power releases from Oahe and Big Bend. Major inflows to Lake Francis Case are the Missouri River and White River. Water discharged through Fort Randall Dam for power production is withdrawn from Lake Francis Case at elevation 1229 ft-NGVD29, approximately 2 feet above the reservoir bottom. Figure 5-21 shows a schematic drawing and photo of the outlet works at Fort Randall Dam.

Table 5-19. Surface area, volume, mean depth, and retention time of Lake Francis Case at different pool elevations based on 1996 bathymetric survey.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1370	98,438	4,916,698	49.9	0.278
1365	94,801	4,433,011	46.7	0.251
1360	89,808	3,971,266	44.2	0.225
1355	85,453	3,531,526	41.3	0.200
1350	76,747	3,124,368	40.7	0.177
1345	68,588	2,761,139	40.3	0.156
1340	59,783	2,439,591	40.8	0.138
1335	50,547	2,165,606	42.8	0.123
1330	45,845	1,926,136	42.0	0.109
1325	40,277	1,711,773	42.5	0.097
1320	37,911	1,517,486	40.0	0.086
1315	35,000	1,335,568	38.2	0.076
1310	33,632	1,164,645	34.6	0.066
1305	32,119	1,000,024	31.1	0.057
1300	30,297	843,949	27.9	0.048
1295	28,608	696,350	24.3	0.039
1290	26,042	559,475	21.5	0.032

Average Annual Inflow (1967 through 2010) = 17.93 Million Acre-Feet.
Average Annual Outflow: (1967 through 2010) = 17.67 Million Acre-Feet.
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1375-1365 ft-NGVD29), Annual Flood Control and Multiple Use Zone (elev. 1365-1350 ft-NGVD29), Carryover Multiple Use Zone (1350-1320 ft-NGVD29), and Permanent Pool Zone (elev. 1320-1227 ft-NGVD29). All elevations are in the NGVD 29 datum.

Lake Francis Case was authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. Over the period 1967 through 2010, the eight generating units at Fort Randall Dam have produced an annual average 1.73 million MWh of electricity. The recent drought in the western United States curtailed releases and power production at the Mainstem System projects, including Fort Randall. Power production at the Fort Randall Dam generating units averaged an annual 1.24 million MWh over the 5-year period 2006 through 2010. Habitat for two endangered species, pallid sturgeon and interior least tern, and one threatened species, piping plover, occur within the project area. Five surface water intakes are located on Lake Sharpe: 1) Chamberlain, SD (RM967); 2) Aurora-Brule Rural Water System (RM966 – Pukwana, Kimball, White Lake, Stickneym, Plankington, Gann Valley, Aurora Center, SD, and approximately 1,000 farms); 3) Oacoma, SD (RM967); and 4 and 5) Randall Community Water District - Platte and Pickstown (RM912 and RM880 – Pickstown, Davidson, Charles Mix, and Douglas, SD). The reservoir is an important recreational resource and a major visitor destination in South Dakota.

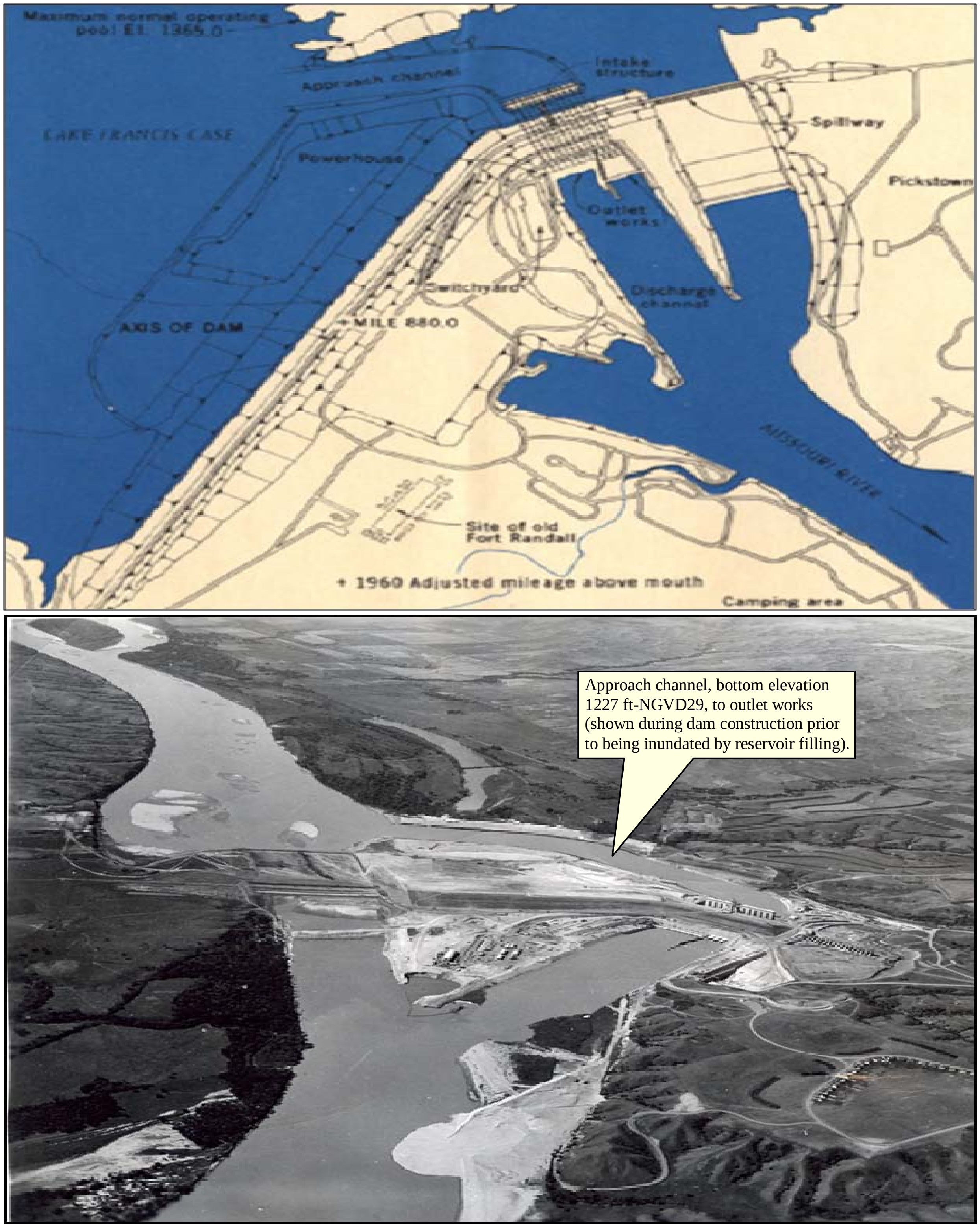


Figure 5-21. Schematic drawing and photo of outlet works at Fort Randall Dam.

5.6.1.2 Water Quality Standards Classification and Section 303(d) Listings

5.6.1.2.1 Lake Francis Case

South Dakota has classified the Missouri River impoundments within the State as flowing streams and not reservoirs (South Dakota Administrative Rules 74:51:01:43). The State of South Dakota has designated the following water quality-dependent beneficial uses for Lake Francis Case in the State's water quality standards: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of South Dakota has not placed Lake Francis Case on the State's Section 303(d) list of impaired waters and has not issued a fish consumption advisory for the reservoir.

5.6.1.2.2 Fort Randall Dam Tailwaters

South Dakota's water quality standards designate the following beneficial uses for the Missouri River downstream of Fort Randall Dam: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of South Dakota has not placed the Missouri River downstream of Fort Randall Dam on the State's Section 303(d) list of impaired waters and has not issued a fish consumption advisory for the river.

5.6.1.2.3 Ambient Water Quality Monitoring

The District has monitored water quality conditions at the Fort Randall Project since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow to and outflow from the reservoir. The water quality conditions of the Big Bend Dam discharge are taken to represent the inflow water quality conditions of the Missouri River to Lake Francis Case. A 3-year intensive water quality survey was completed at the Fort Randall Project in 2008, and the findings of the intensive survey are available in the separate report, "Water Quality Conditions Monitored at the Corps' Fort Randall Project in South Dakota during the 3-Year period 2006 through 2008" (USACE, 2009b). Figure 5-22 shows the location of sites at the Fort Randall Project that have been monitored for water quality during the 5-year period 2006 through 2010. The near-dam location (i.e., site FTRLK0880A) has been continuously monitored since 1980.

5.6.2 WATER QUALITY IN LAKE FRANCIS CASE

5.6.2.1 Existing Water Quality Conditions

5.6.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Water quality conditions that were monitored in Lake Francis Case at sites FTRLK0880A, FTRLK0892DW, FTRLK0911DW, FTRLK0924DW, FTRLK0940DW, FTRLK0955DW, and FTRLK0968DW from May through September during the 5-year period 2006 through 2010 are summarized in Plate 285, Plate 286, Plate 287, Plate 288, Plate 289, Plate 290, and Plate 291. A review of these results indicated possible water quality concerns regarding dissolved oxygen and suspended solids for the support of Warmwater Permanent Fish Life Propagation. Dissolved oxygen levels degrade along the reservoir bottom as summer progresses and fall below 5.0 mg/l in July and August. The lowest dissolved oxygen concentration measured at the seven sites was 0.1 mg/l and occurred at the reservoir bottom at site FTRLK0955DW in June 2008. The chronic suspended solids criterion was exceeded in Lake Francis Case in the area near the confluence of the White River (Plate 289).

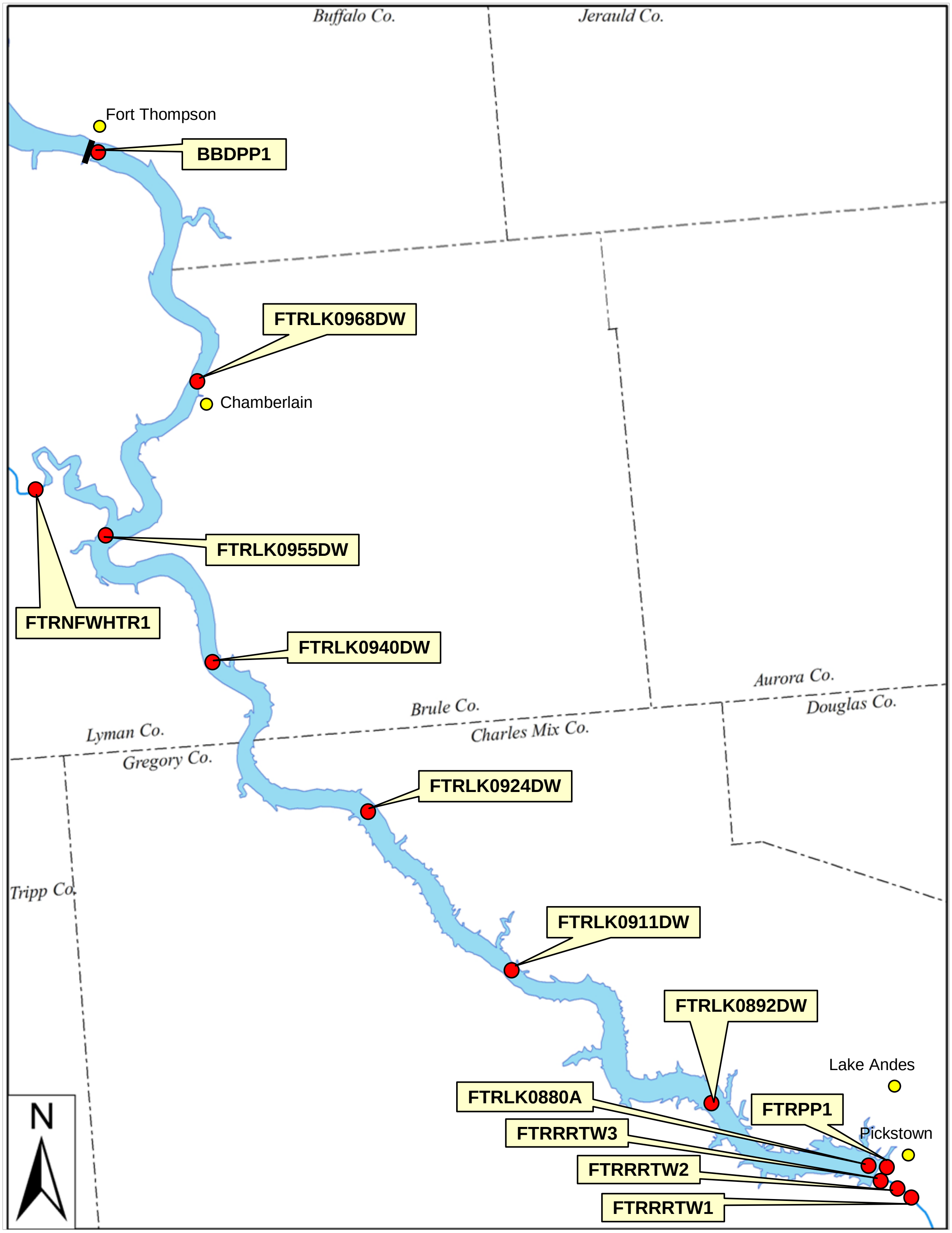


Figure 5-22. Location of sites where water quality monitoring was conducted by the District at the Fort Randall Project during the 5-year period 2006 through 2010.

5.6.2.1.2 Summer Thermal Stratification

5.6.2.1.2.1 Monthly Longitudinal Temperature Contour Plots

Summer thermal stratification of Lake Francis Case during 2010 is described by the monthly longitudinal temperature contour plots based on depth-profile temperature measurements taken in May, June, July, August, and September (Plate 292, Plate 293, Plate 294, Plate 295, and Plate 296). The contour plots were constructed along the length of the reservoir. As seen in the contour plots, water temperature in Lake Francis Case varies longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Water temperatures in the upstream reaches of the reservoir are influenced by the discharges from Big Bend Dam (RM987) and inflows from the White River (RM956). In late-spring to mid-summer an appreciable vertical thermal gradient was present in the lacustrine, downstream region of the reservoir. By late summer this vertical thermal gradient had greatly diminished greatly.

5.6.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Lake Francis Case in the deep water area near the dam is described by the depth-profile temperature measurements taken over the 5-year period 2006 through 2010. Depth-profile temperatures measured during the summer months at site FTRLK0880A were compiled and plotted (Plate 297). The depth-profile temperature plots indicate that a moderate temperature-depth gradient occasionally occurred in the summer in the deeper area of Lake Francis Case near the dam, and a significant thermocline developed at a depth of about 20 to 25 meters. Thermal stratification breaks down in late summer as water column mixing is seemingly induced by reservoir drawdown, warming of the hypolimnion, and bottom withdrawals from the reservoir.

5.6.2.1.3 Summer Dissolved Oxygen Conditions

5.6.2.1.3.1 Monthly Longitudinal Dissolved Oxygen Contour Plots

Dissolved oxygen contour plots were constructed along the length of Lake Francis Case based on depth-profile measurements taken in May, June, July, August, and September of 2010 (Plate 298, Plate 299, Plate 300, Plate 301, and Plate 302). During the summer of 2010, dissolved oxygen conditions in Lake Francis Case varied longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. A significant area of low dissolved oxygen (i.e., <5 mg/l) occurred in the downstream area of the reservoir near the dam. The area of low dissolved oxygen occurred along the reservoir bottom in the hypolimnion, and dissipated in late-August and September when thermal stratification broke down and reservoir mixing occurred.

5.6.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Dissolved oxygen depth-profiles measured during the summer at site FTRLK0880A over the 5-year period 2006 through 2010 were plotted (Plate 303). Dissolved oxygen levels exhibited occasional gradients with depth. On seven occasions (i.e., July 2006, July 2007, July 2009, July 2010, August 2007, August 2008, and August 2010), hypolimnetic dissolved concentrations fell below 5.0 mg/l. Dissolved oxygen levels below 5 mg/l occurred near the reservoir bottom from mid-July through August, when thermal stratification was maintained in Lake Francis Case.

5.6.2.1.4 Water Clarity

5.6.2.1.4.1 Secchi Transparency

Figure 5-23 displays a box plot of the Secchi depth transparencies measured along Lake Francis Case at five sites FTRLK0880, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and Big Bend Dam tailwaters during the 5-year period 2006 through 2010. The Secchi depth of the Big Bend Dam tailwaters was taken to be the Secchi depth measured in Lake Sharpe at the near-dam monitoring site (i.e., BBDLK0987A). The inflow of the White River to Lake Francis Case is between monitoring sites FTRLK0940DW and FTRLK0968DW at RM956. Secchi depth transparency significantly decreased from the Big Bend Dam tailwaters to the upstream reaches of Lake Francis Case. The lower transparencies in the upstream reaches of the reservoir are attributed to the shallowness of the reservoir in this area and the resuspension of deposited bottom sediments with wind and wave action. Water transparency generally increased in a downstream direction from the upstream reaches of the reservoir to near the dam. However, the inflow of the White River seemingly maintained reduced the transparencies in the upstream reaches of the reservoir. The near-surface transparency of Lake Francis Case measured near the dam was significantly higher than the transparency measured in upstream reaches of the reservoir.

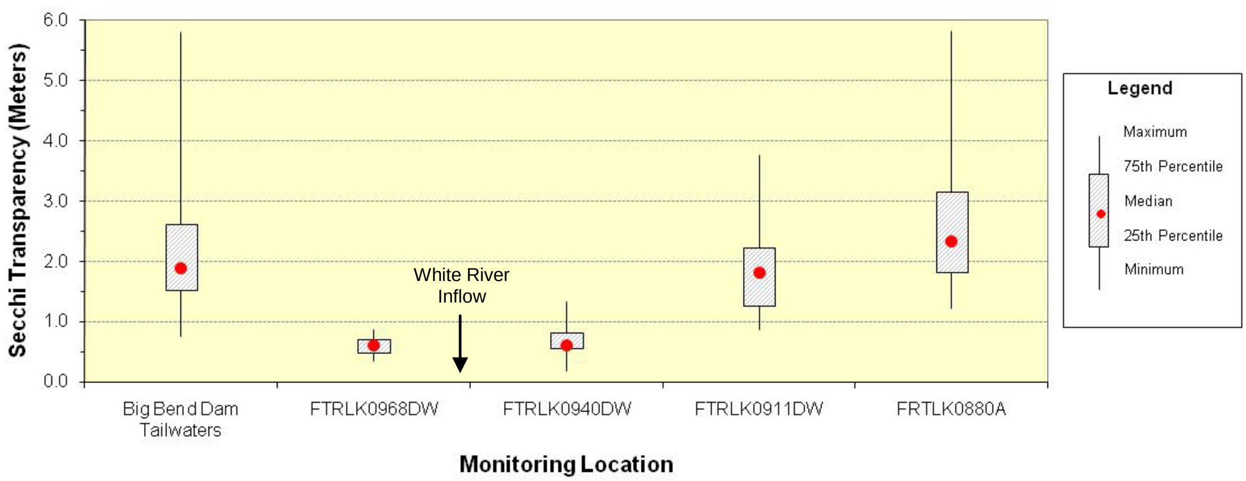


Figure 5-23. Box plot of Secchi transparencies measured along Lake Francis Case during the 5-year period 2006 through 2010. (Note: monitoring sites are oriented on the x-axis in an upstream to downstream direction.)

5.6.2.1.4.2 Turbidity

Monthly (i.e., May, June, July, August, and September) longitudinal contour plots were prepared from the depth-profile turbidity measurements taken at sites FRTLK0880A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW and BBDPP1 during 2010 (Plate 304, Plate 305, Plate 306, Plate 307, and Plate 308). As seen in the contour plots, turbidity levels monitored in Lake Francis Case during 2010 showed little longitudinal and vertical variation. This is markedly different from the turbidity conditions monitored in 2008 (see 2008 Report – Water Quality Conditions in the Missouri River Mainstem System, USACE 2009c). In 2008, the inflow of the White River significantly increased the turbidity of Lake Francis Case in the upper reaches of the reservoir. Elevated levels of turbidity attributable to the inflow of the White River were regularly seen in Fort Randall Reservoir up to 25 miles downstream from the White River inflow.

5.6.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Lake Francis Case during the summer were compared. Near-surface conditions were represented by samples collected within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 1-meter of the reservoir bottom. The compared samples were collected at the near-dam site FTPLK0880A during the 5-year period 2006 through 2010. During the period a total of 24 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Plate 309). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different (α = 0.05). The sampled near-surface and near-bottom conditions were significantly different for water temperature, dissolved oxygen, ORP, and pH. Parameters that were significantly lower in the near-bottom water of Lake Francis Case included: water temperature ($p < 0.001$), dissolved oxygen ($p < 0.001$), and pH ($p < 0.001$). Parameters that were significantly higher in the near-bottom water included: ORP ($p < 0.001$).

5.6.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Lake Francis Case were calculated from monitoring data collected at sites FTRLK0880A, FTRLK0911DW, FTRLK0940DW, and FTRLK0968DW during the 5-year period 2006 through 2010 (Table 5-20). The calculated TSI values indicate that the lacustrine zone of the reservoir near the dam (site FTRLK0880A) is mesotrophic, the area near site FTRLK0911DW is moderately eutrophic, and the upstream transition and riverine zones of the reservoir (sites FTRLK940DW and FTRLK0968DWDW) are eutrophic.

Table 5-20. Mean Trophic State Index (TSI) values calculated for Lake Francis Case. TSI values are based on monitoring at the identified four sites during the 5-year period 2006 through 2010.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
FTRLK0880A	47	52	50	50
FTRLK0911DW	52	51	55	52
FTRLK0940DW	66	52	59	59
FTRLK0968DW	68	55	59	61

Note: See Section 4.1.4 for discussion of TSI calculation.

5.6.2.1.7 Plankton Community

5.6.2.1.7.1 Phytoplankton

Phytoplankton grab samples collected from Lake Francis Case at sites FTRLK0880A, FTRLK0911DW, FTRLK0940DW, and FTRLK0968DW during the spring and summer over the 5-year period 2006 through 2010 are summarized in Plate 310, Plate 311, Plate 312, and Plate 313. The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The relative abundance of phytoplankton in samples collected from

Lake Francis Case in May, July, and September 2010, based on biovolume, is shown in Figure 5-24. Diatoms (Bacillariophyta) are by far the most dominant phytoplankton group present in Lake Francis Case. Major phytoplankton genera sampled in Lake Francis Case during 2010 (i.e., genera comprising more than 10% of the total biovolume of at least one sample) included the Bacillariophyta *Asterionella*, *Aulacoseria*, *Fragilaria*, and *Tabellaria*; and the Cryptophyta *Rhodomonas*. No concentrations of the cyanobacteria toxin microcystin above 2 ug/l were monitored in the reservoir during the 5-year period 2006 through 2010 (Plate 285, Plate 287, Plate 289, and Plate 291).

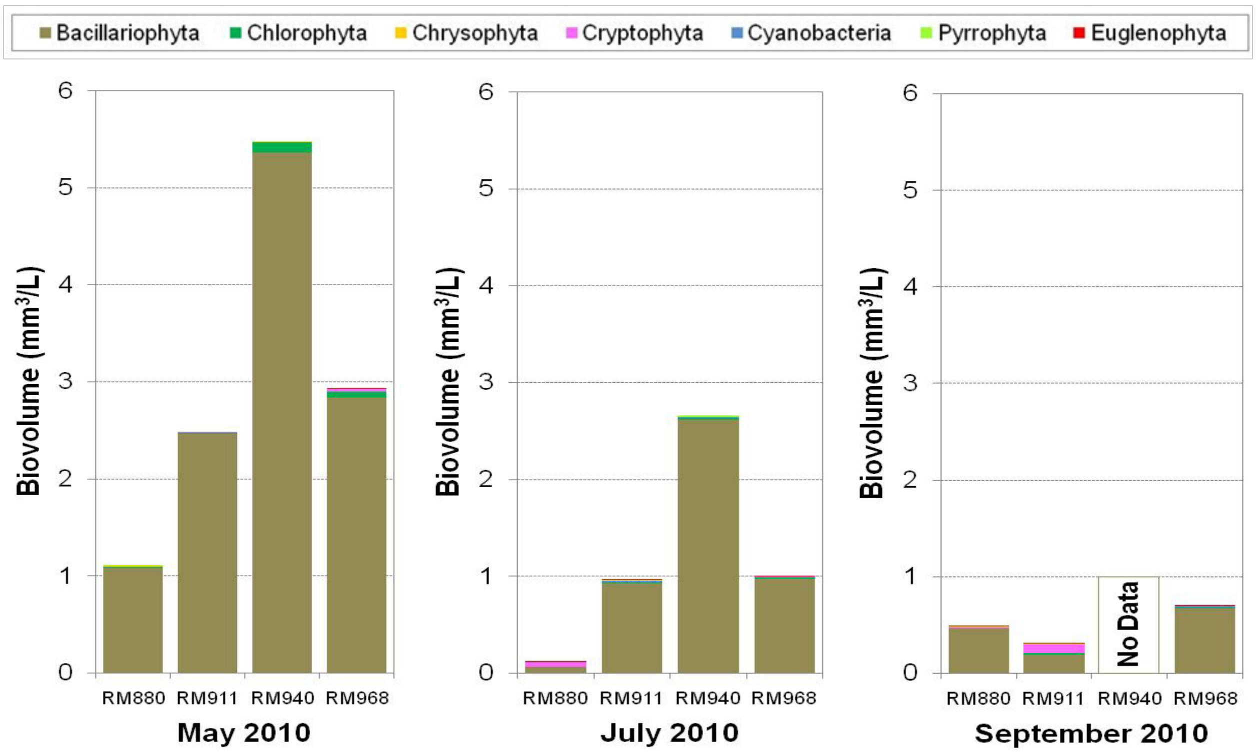


Figure 5-24. Relative abundance of phytoplankton in samples collected from Lake Francis Case during 2010.

5.6.2.1.7.2 Zooplankton

Zooplankton vertical-tow samples were collected from Lake Francis Case at sites FTRLK0880A, FTRLK0911DW, FTRLK0940DW, and FTRLK0968DWDW in May, July, and September of 2010 (Plate 314). The sampled zooplankton included three taxonomic groupings: Cladocerans, Copepods, and Rotifers. The relative abundance of these three taxonomic grouping in the zooplankton samples collected in 2010 is shown in Figure 5-25. Cladocerans and copepods dominated the zooplankton community in Lake Francis Case. Major zooplankton species sampled in Lake Francis Case during 2010 (i.e., species comprising more than 10% of the total biomass of at least one sample) included Cladocerans *Bosmina longirostris*, *Daphnia pulex*, *Daphnia retrocurva*, and *Leptodora kindtii*; Copepods *Acanthocyclops vernalis*, *Calanoid copepodid*, *Cyclopoid copepodid*, *Diacyclops*, *thomasi*, and *Mesocyclops edax*; and Rotifers *Asplanchna spp.*, and *Polyarthra vulgaris.* Dominant species (i.e., species comprising more than 25% of the total biomass of at least one sample) included Cladocerans *Daphnia pulex*, and *Daphnia retrocurva*; Copepods *Acanthocyclops vernalis*, *Cyclopoid copepodid*, and *Diacyclops thomasi*, and Rotifers *Asplanchna spp.*

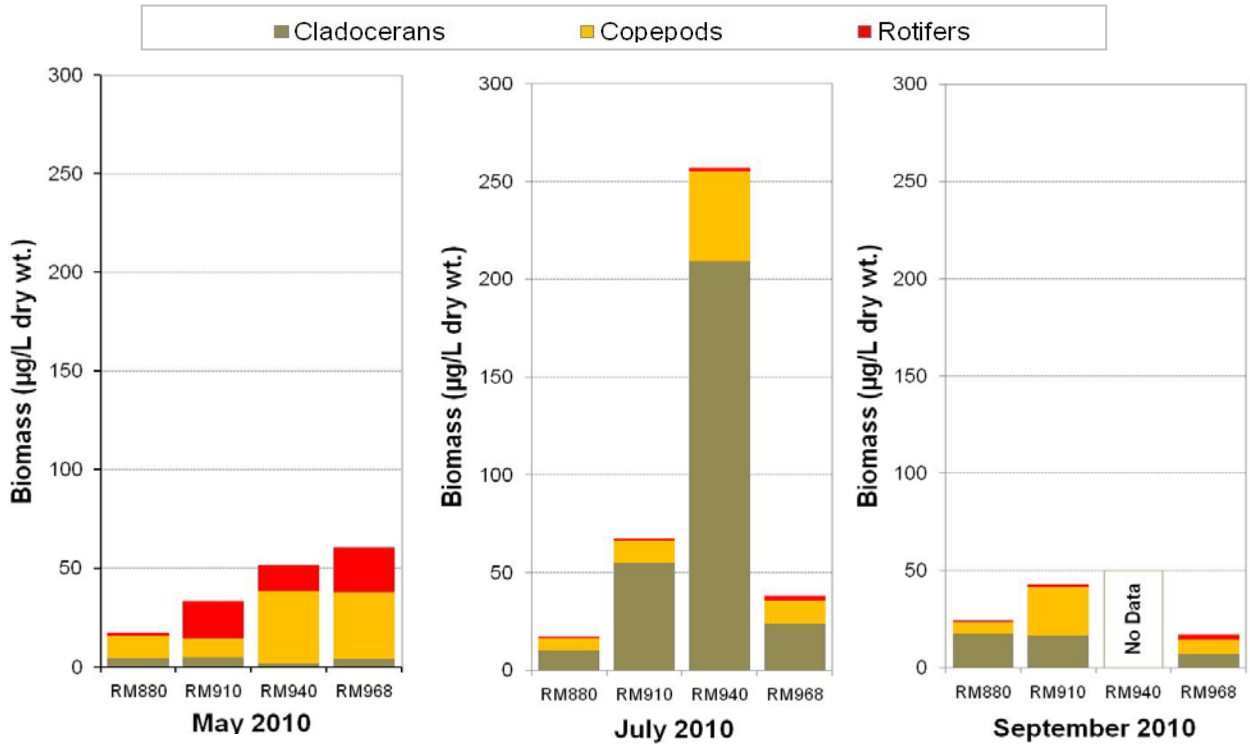


Figure 5-25. Relative abundance of zooplankton in samples collected from Lake Francis Case during 2010**.**

5.6.2.1.8 Impairment of Designated Water Quality Beneficial Uses

Based on the State of South Dakota's impairment assessment methodology (Section 4.1.6.4), the water quality conditions monitored in Lake Francis Case during the 5-year period 2006 through 2010 did not indicate impairment of any designated water quality beneficial uses.

5.6.2.2 <u>Water Quality Trends (1980 through 2010)</u>

Water quality trends over the 31-period of 1980 through 2010 were determined for Lake Francis Case for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam, ambient monitoring site (i.e., site FTRLK0880A). Plate 315 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, Lake Francis Case exhibited a significant decreasing trend for Secchi depth and a significant increasing trend for TSI. No significant trends were detected for total phosphorus or chlorophyll *a*. Over the 31-year period, the downstream reach of Lake Francis Case has generally remained in a mesotrophic state.

5.6.3 EXISTING WATER QUALITY CONDITIONS OF THE MISSOURI RIVER INFLOW TO LAKE FRANCIS CASE

5.6.3.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions of the Missouri River inflow to Lake Francis Case is taken to be the monitored water quality conditions of the outflow from Big Bend Dam. See Plate 258 and Plate 259 for a summary of the water quality conditions monitored on the water discharged through Big Bend Dam.

5.6.3.2 Missouri River Inflow Nutrient Flux Conditions

Nutrient flux rates for the Missouri River inflow to Lake Francis Case over the last 5 years were calculated based on water quality conditions monitored on water discharged through Big Bend Dam (i.e. site BBDPP1). See Table 5-18 for the nutrient flux rates calculated for the monitored Big Bend Dam discharges.

5.6.3.3 Mean Daily Discharge and Temperature

Mean daily discharge and water temperature of the Big Bend Dam outflow were determined for 2006, 2007, 2008, 2009, and 2010. These are considered the water quality conditions of the Missouri River inflow to Lake Francis Case. Plate 316, Plate 317, Plate 318, Plate 319, and Plate 320, respectively, plot 2006, 2007, 2008, 2009, and 2010 mean daily water temperature and flow for the Big Bend Dam discharge.

5.6.4 WATER QUALITY AT THE FORT RANDALL POWERPLANT

5.6.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 321 and Plate 322 summarize the water quality conditions that were monitored on water discharged through Fort Randall Dam during the 5-year period 2006 through 2010. A review of these results indicated no major water quality concerns.

5.6.4.2 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Semiannual time series plots for temperature and dam discharge monitored at the Fort Randall powerplant during the 5-year period of 2006 through 2010 were constructed (Plate 323 - Plate 332). Monitored water temperatures showed seasonal cooling and warming through each calendar year. Daily water temperatures remained fairly stable during the winter, early spring, and fall and exhibited considerable variability during the late spring and summer. When thermal stratification becomes established in Lake Francis Case during the late spring, the temperature of the water discharged through the dam becomes highly dependent upon the discharge rate of the dam. This indicates that the vertical extent of the withdrawal zone in the reservoir is dependent upon the discharge rate of the dam. This is believed to be a result of the design of the intake structure (i.e., bottom withdrawal) and the presence of the submerged approach channel leading to the intake structure. Water is likely drawn from an extended vertical zone in Lake Francis Case year-round, but is only evident in the temperatures monitored at the powerhouse during reservoir thermal stratification during the summer. When thermal stratification breaks down in the summer, the high correlation between dam discharge and the temperature of the discharged water no longer occurs. This occurred in late-July in 2006 (Plate 324), September 1, 2007 (Plate 326), September 1, 2008 (Plate 328), mid-August 2009 (Plate 330), and early-August 2010 (Plate 332).

Semiannual time series plots for dissolved oxygen and dam discharge monitored at the Fort Randall powerplant during the 5-year period of 2006 through 2010 were also constructed (Plate 333 - Plate 342). (Note: *Due to equipment failure, no dissolved oxygen measurements were recorded in 2008 after early June.)* Dissolved oxygen levels remained relatively high and stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall. The lowest dissolved oxygen levels occurred during mid-summer. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. The decreasing dissolved oxygen in the summer is attributed to ongoing degradation of dissolved oxygen in the lower hypolimnion as the summer progressed. Water is withdrawn from Lake Francis Case into the dam's power tunnels approximately 2 feet above the reservoir bottom. During the summer when Lake Francis Case is thermally stratified, dissolved oxygen levels degrade near the reservoir bottom. Under such conditions, low dam discharge rates pull water with low dissolved oxygen concentrations from the near-bottom region of the hypolimnion.

As seen in the time series plots, dissolved oxygen levels monitored during the summer go below the 5 mg/l criterion established for the protection of the Warmwater Permanent Fish Life Propagation use. The lower dissolved oxygen levels appear to be associated with lower discharge conditions when water is drawn into the penstocks along the reservoir bottom. Seemingly, the low dissolved oxygen levels are related to oxygen degradation in the reservoir hypolimnion during the summer. During periods of lower discharge, water is drawn along the bottom of the submerged approach channel to the dam's intake tower. This is where low dissolved oxygen would occur in the hypolimnion during mid- to late summer. To further evaluate this situation a Special Water Quality Study was conducted during the summer of 2010 to evaluate low dissolved oxygen levels in the powerplant discharges and the tailwaters of Fort Randall Dam.

5.6.4.3 Findings of the 2010 Special Water Quality Study of Dissolved Oxygen Conditions in the Fort Randall Dam Tailwaters

Findings of the 2010 Special Water Quality Study are presented in the document, "Low Dissolved Oxygen Levels in Summer Powerplant Discharges from Fort Randall Dam, South Dakota", (USACE, 2010). The following conclusions were taken from that report:

> *Thermal stratification of Lake Francis Case during the summer results in the development of hypoxic conditions in the reservoir's hypolimnion. Lake Francis Case is a bottom-release reservoir, and hypoxic water is passed through Fort Randall Dam during power production during July and August. Under these conditions, dissolved oxygen levels in areas of the Fort Randall Dam tailwaters fall below South Dakota's water quality standards' minimum dissolved oxygen criterion of 5 mg/l. Monitored conditions indicate that the low dissolved oxygen levels in the tailwaters are not seemingly impairing the designated Warmwater Permanent Fish Life Propagation beneficial use as regions of refugia exist in the impacted area. Also, there is no evidence of past fish kills in the Fort Randall tailwaters attributable to hypoxic conditions. If warranted, dissolved oxygen conditions in the Fort Randall tailwaters during periods of hypoxic dam releases could be mitigated by drawing water from the reservoir surface and spilling it down the spillway into the tailwaters.*

5.6.4.4 Impairment of Designated Water Quality Beneficial Uses

Based on the State of South Dakota's impairment assessment methodology (Section 4.1.6.4), the water quality conditions monitored in Fort Randall Dam discharge during the 5-year period 2006 through 2010 did not indicate impairment of any designated water quality beneficial uses of the downstream Missouri River.

5.6.4.5 Comparison of Monitored Inflow and Outflow Temperatures of the Missouri River at Lake Francis Case

Plate 343, Plate 344, Plate 345, Plate 346, and Plate 347, respectively, plot the mean daily water temperatures monitored for the Missouri River at Big Bend (site BBDPP1) and the Fort Randall powerplants (site FTRPP1) for 2006, 2007, 2008, 2009, and 2010. Inflow temperatures of the Missouri River to Lake Francis Case tend to be at little warmer than the outflow temperatures of Fort Randall Dam during the spring and early summer. Outflow temperatures of the Fort Randall Dam discharge tend to be a little warmer than the Missouri River inflow temperatures in the late-summer and fall.

5.6.4.6 Nutrient Flux Conditions of the Fort Randall Dam Discharge to the Missouri River

Nutrient flux rates for the Fort Randall Dam discharge to the Missouri River over the 5-year period 2006 through 2010 were calculated based on samples taken from the Fort Randall powerplant (i.e. site FTRPP1) and the dam discharge at the time of sample collection (Table 5-21). The samples collected in the powerplant are taken from the raw water supply line and are believed to be unbiased regarding particulate-associated constituents. Therefore, the flux rates calculated for the Fort Randall Dam discharge give an unbiased estimate of the flux rates for all the constituents, including total phosphorus and total organic carbon. The maximum flux rates for all the constituents are believed to be attributed to higher dam discharges.

Table 5-21. Summary of nutrient flux rates (kg/sec) calculated for the Fort Randall Dam discharge to the Missouri River (i.e., site FTRPP1) during January through December over the 5-year period 2006 through 2010.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	50	50	50	50	50	47	48
Mean	21,328	0.0184	0.2632	0.0443	0.0151	0.0099	2.0991
Median	19,222	n.d.	0.2043	n.d.	0.0108	n.d.	1.6841
Minimum	0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	47,869	0.1551	1.0179	0.4593	0.0748	0.0560	6.2702

Note: Nondetectable values set to 0 for flux calculations.

5.6.5 WATER QUALITY IN THE MISSOURI RIVER DOWNSTREAM OF FORT RANDALL DAM

5.6.5.1 Missouri River Reach – Fort Randall Dam to Lewis and Clark Lake

The Missouri River downstream from Fort Randall Dam (RM880) flows in a southeasterly direction for approximately 44 miles in an unchannelized river to Lewis and Clark Lake. The major tributary in this reach is the Niobrara River which enters the Missouri River from Nebraska at RM843.5. In this reach, the Missouri River meanders in a wide channel with flow restricted to generally one main channel. Only a few side channels and backwaters are present, except at the lower end of the reach in the Lewis and Clark Lake delta. The 39-mile reach of the Missouri River from Fort Randall Dam to Running Water, SD has been designated a National Recreational River under the Federal Wild and Scenic Rivers Act (WSRA). The tailwater area of Fort Randall Dam, from RM880 to RM860, has experienced up to 6 feet of riverbed degradation and channel widening during the 1953 to 1997 time period. The rate of erosion has decreased over this period. Streambank erosion since closure of the dam in 1953 has

averaged about 35 acres per year. This compares to a pre-dam rate of 135 acres per year. The Missouri River has coarser bed material above RM870 than below, indicating some armoring of the channel immediately downstream of the dam. Downstream of the tailwater area, less erosion of the bed and streambank occurs.

5.6.5.1.1 National Recreation River Designation Pursuant to the Federal Wild and Scenic Rivers Act

The 39-mile "natural-channel" reach of the Missouri River from Fort Randall Dam to the headwaters of Lewis and Clark Lake has been designated as a National Recreational River under the Federal WSRA. The National Park Service (NPS) manages the 39-mile reach pursuant to the WSRA. The justification that supported that this reach of the Missouri River be protected as a recreational river identified its outstanding remarkable recreational, fish and wildlife, aesthetic, historical, and cultural values. Under the WSRA, the U.S. Department of Interior (i.e., NPS) is mandated to administer this reach in a manner that will protect and enhance these values for the benefit and enjoyment of present and future generations.

5.6.5.1.2 State Designations and Listings Pursuant to the Federal Clean Water Act

Pursuant to the Federal Clean Water Act (CWA), the States of South Dakota and Nebraska have designated water quality-dependent beneficial uses, in their State water quality standards, for the Missouri River from of Fort Randall Dam to Lewis and Clark Lake. South Dakota has designated the following uses for this reach of the Missouri River: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. Nebraska has designated the following uses to this reach of the Missouri River: primary contact recreation, Class I warmwater aquatic life, agricultural water supply, and aesthetics. It has designated the use of drinking water supply to the river below the confluence of the Niobrara River. Nebraska has also designated the reach between the Nebraska-South Dakota border and Lewis and Clark Lake an Outstanding State Resource Water for "Tier 3" protection under the water quality standard's antidegradation policy. Neither of the States has placed this reach of the Missouri River on their Section 303(d) list of impaired waters, nor has issued a fish consumption advisory for this reach of the Missouri River.

The national interpretation with respect to the Outstanding National Resource Waters protected under "Tier 3" of the antidegradation policy is that no new or increased discharges are allowed. The only exception to this is that States (i.e., Nebraska) may allow some limited activities which result in temporary and short-term changes in water quality.

5.6.5.2 Monitored Water Quality Conditions

The District, in cooperation with the Nebraska Department of Environmental Quality, conducted fixed-station water quality monitoring at two sites along the Missouri River from Fort Randall Dam to Lewis and Clark Lake. The locations of the two sites were Fort Randall Dam tailwaters (site FTRRRTW1) and the Missouri River near Verdel, NE (site MORRR0851) (see Figure 5-26). During the 5-year period of 2006 through 2010, water quality samples were collected monthly from October through March and monthly to biweekly from April through September. Plate 348 and Plate 349 summarize the water quality conditions that were monitored at the two sites. A review of these results indicated no major water quality concerns.

5.7 GAVINS POINT

5.7.1 BACKGROUND INFORMATION

5.7.1.1 Project Overview

Gavins Point Dam is located on the Missouri River at RM 811.1 on the South Dakota-Nebraska border in southeast South Dakota and northeast Nebraska, 4 miles west of Yankton, SD. The closing of Gavins Point Dam in 1955 resulted in the formation of Gavins Point Reservoir (Lewis and Clark Lake). The reservoir is 25 miles long, covers 31,000 acres, and has 90 miles of shoreline when full. Table 5-22 summarizes how the surface area, volume, mean depth, and retention time of Lewis and Clark Lake vary with pool elevations. Lewis and Clark Lake is normally regulated near 1206.0 ft-NGVD29 in the spring and early summer with variations day to day due to rainfall runoff. The reservoir level is then increased to elevation 1207.5 ft-NGVD29 following the least tern and piping plover nesting season for reservoir recreation enhancement. Major inflows to Lewis and Clark Lake are the Missouri River and Niobrara River. Water discharged through Gavins Point Dam for power production is withdrawn from the bottom of Lewis and Clark Lake at an invert elevation of 1139.5 ft-NGVD29.

Table 5-22. Surface area, volume, mean depth, and retention time of Lewis and Clark Lake at different pool elevations based on 2007 bathymetric survey.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1210	29,956	450,070	15.0	0.02293
1205	23,029	318,732	13.8	0.01624
1200	18,819	215,126	11.4	0.01096
1195	14,278	132,308	9.3	0.00674
1190	9,921	71,711	7.2	0.00365
1185	5,202	35,027	6.7	0.00178
1180	3,393	14,543	4.3	0.00074
1175	1,067	3,855	3.6	0.00020
1170	371	728	2.0	0.00004

Average Annual Inflow (1967 through 2010) = 19.67 Million Acre-Feet.
Average Annual Outflow: (1967 through 2010) = 19.63 Million Acre-Feet.
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1210-1208 ft-NGVD29), Annual Flood Control and Multiple Use Zone (elev. 1208-1204.5 ft-NGVD29), Carryover Multiple Use Zone (none), and Permanent Pool Zone (elev. 1204.5-1160 ft-NGVD29). All elevations are in the NGVD 29 datum.

Gavins Point was authorized for the proposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. Over the period 1967 through 2010, the three generating units at Gavins Point Dam have produced an annual average 0.727 million MWh of electricity. The recent drought in the western United States curtailed releases and power production at the Mainstem System projects, including Gavins Point. Power production at the Gavins Point Dam generating units averaged an annual 0.601 MWh over the 5-year period 2006 through 2010. Habitat for two endangered species, pallid sturgeon and interior least tern, and one threatened species, piping plover, occur within the project area. Lewis and Clark Lake is a source water supply (drinking water) for Springfield, SD (RM832); Cedar Knox Rural Water District (RM823 – Crofton, Fordice, St. Helena, and Obert, NE); and Bon Homme-Yankton Rural Water District (RM818 – 15 communities). Gavins Point is an important recreational resource and a major visitor destination in South Dakota and Nebraska.

5.7.1.2 Water Quality Standards Classifications and Section 303(d) Listings

5.7.1.2.1 Lewis and Clark Lake

Pursuant to the Federal Clean Water Act, the State of South Dakota has designated the following water quality-dependent beneficial uses for Lewis and Clark Lake: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of Nebraska has designated the following beneficial uses to Lewis and Clark Lake: primary contact recreation, Class I warmwater aquatic life, drinking water supply, agricultural water supply, industrial water supply, and aesthetics. The uses designated by the States of South Dakota and Nebraska to Lewis and Clark Lake are consistent with each other. Nebraska has placed Lewis and Clark Lake on the State's 2010 Section 303(d) list of impaired waters for impairment to the Aquatic Life use due to nutrients (total phosphorus and total nitrogen). Neither of the two States has issued fish consumption advisories for the reservoir.

5.7.1.2.2 Missouri River Downstream of Gavins Point Dam

See Section 6 for a discussion of the Lower Missouri River downstream of Gavins Point Dam.

5.7.1.3 Ambient Water Quality Monitoring

The District has monitored water quality conditions at the Gavins Point Project since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow to and outflow from the reservoir. A 3-year intensive water quality survey was completed in 2010 and the findings of the intensive survey are available in the separate report, "Water Quality Conditions Monitored at the Corps' Gavins Point Project in Nebraska/South Dakota during the 3-Year period 2008 through 2010" (USACE, 2011c). An investigative study to evaluate the water quality impacts of constructing emergent sandbar habitat (ESH) in the headwaters of Lewis and Clark Lake was conducted in 2008 and the findings of that study are available in the separate report, "Creation of Emergent Sandbar Habitat (ESH) in the Headwaters of Lewis and Clark Lake and the Impacts on Water Quality" (USACE, 2009d). Figure 5-26 shows the location of sites at the Gavins Point Project that have been monitored by the District for water quality during the 5-year period 2006 through 2010. The near-dam location (i.e., site GPTLK0811A) has been continuously monitored since 1980.

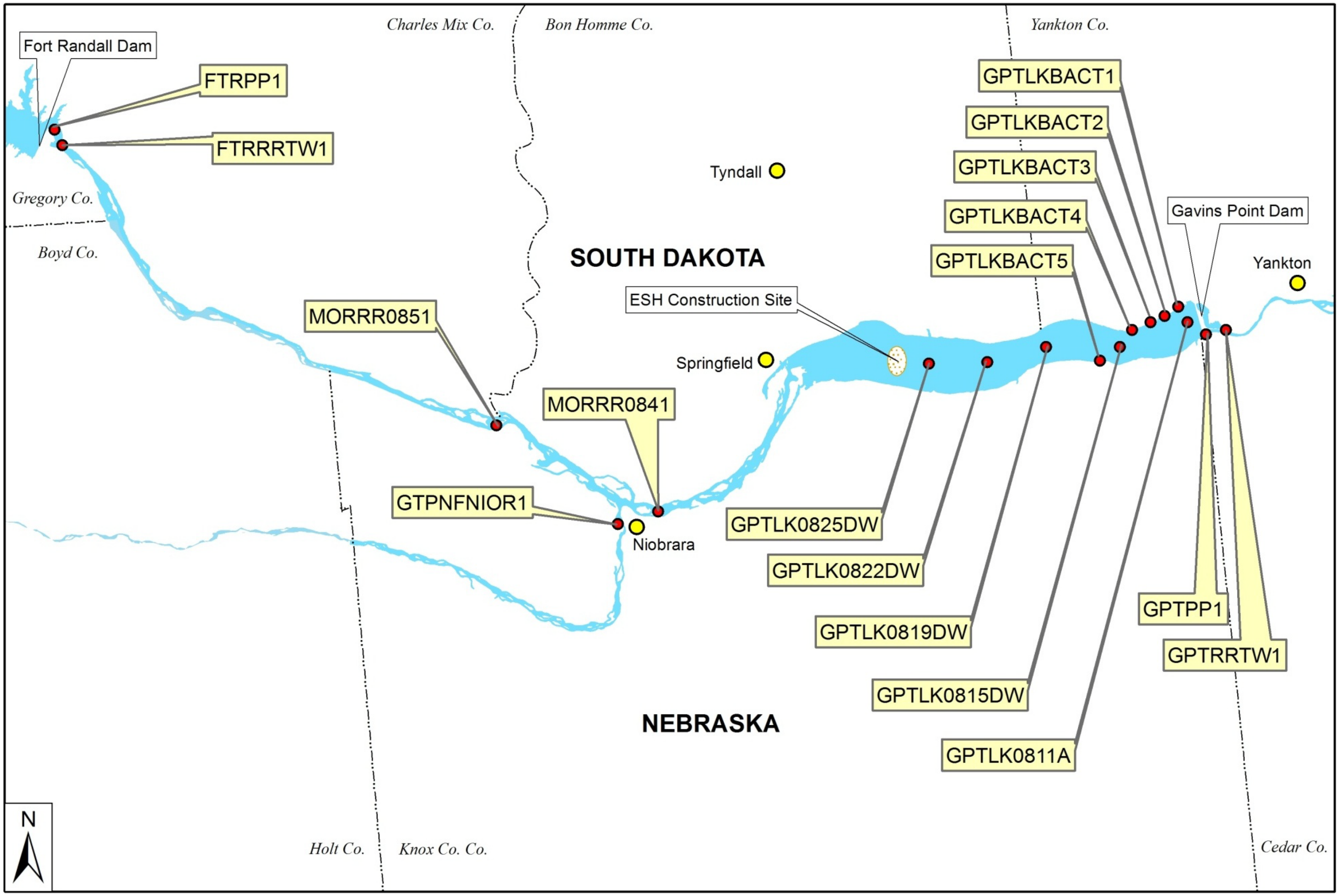


Figure 5-26. Location of sites where water quality monitoring was conducted by the District at the Gavins Point Project during the 5-year period 2006 to 2010.

5.7.2 WATER QUALITY IN LEWIS AND CLARK LAKE

5.7.2.1 Existing Water Quality Conditions

5.7.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Water quality conditions that were monitored in Lewis and Clark Lake at sites GTPLK0811A, GTPLK0815DW, GTPLK0819DW, GTPLK0822DW, and GTPLK0825DW from May through September during the 5-year period 2006 through 2010 are summarized in Plate 350, Plate 351, Plate 352, Plate 353, and Plate 354. A review of these results indicated possible water quality concerns regarding total phosphorus and chlorophyll *a*. The Nebraska "nutrient criteria" for total phosphorus and chlorophyll *a* applicable to Lewis and Clark Lake were regularly exceeded throughout the reservoir.

5.7.2.1.2 Summer Thermal Stratification

5.7.2.1.2.1 Monthly Longitudinal Temperature Contour Plots

Summer thermal stratification of Lewis and Clark Lake during 2010 is described by the monthly longitudinal temperature contour plots based on depth-profile temperature measurements taken in June, July, August, and September (Plate 355, Plate 356, Plate 357, and Plate 358). The contour plots were constructed along the length of the reservoir. As seen in the contour plots, water temperature in Lewis and Clark Lake varies longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Although some summer thermal stratification of Lewis and Clark Lake can occur, the relative shallowness, short retention time, and bottom withdrawal of the reservoir seemingly inhibit the formation of a strong thermocline and long-lasting stratification during the summer.

5.7.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Lewis and Clark Lake at the deep water area near the dam is described by the depth-profile temperature plots measured over the 5-year period 2006 through 2010. Depth-profile temperature plots measured during the summer months were compiled (Plate 359). Minor temperature-depth gradients occasionally occur in Lewis and Clark Lake in the near-dam area during the summer.

5.7.2.1.3 Summer Dissolved Oxygen Conditions

5.7.2.1.3.1 Monthly Longitudinal Dissolved Oxygen Contour Plots

Dissolved oxygen longitudinal contour plots were constructed along the length of Lewis and Clark Lake based on depth-profile measurements taken in June, July, August, and September of 2010 (Plate 360, Plate 361, Plate 362, and Plate 363). During the summer of 2010, dissolved oxygen conditions in Lewis and Clark Lake varied longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Dissolved oxygen levels below 5 mg/l were measured at the reservoir bottom near the dam in July.

5.7.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Existing summer dissolved oxygen conditions in Lewis and Clark Lake at the deep-water area near the dam are described by the depth-profile dissolved oxygen plots measured over the 5-year period 2006 through 2010. Depth-profile dissolved oxygen plots measured during the summer months at site GPTLK0811A were compiled (Plate 364). Dissolved oxygen levels below 5 mg/l regularly occurred near the bottom of the reservoir, and levels near the reservoir bottom were less than 2 mg/l on one occasion.

5.7.2.1.4 Water Clarity

5.7.2.1.4.1 Secchi Transparency

Figure 5-27 displays a box plot of the Secchi depth transparencies measured along Lewis and Clark Lake at the five sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW during the 3-year period 2008 through 2010. Secchi depth transparency increased in a downstream direction from the upper reaches of the reservoir to near the dam. This is attributed to suspended sediment in the inflowing Niobrara and Missouri Rivers settling out in the reservoir as current velocities slow. The surface waters near Gavins Point Dam are significantly clearer than the upstream regions of the reservoir.

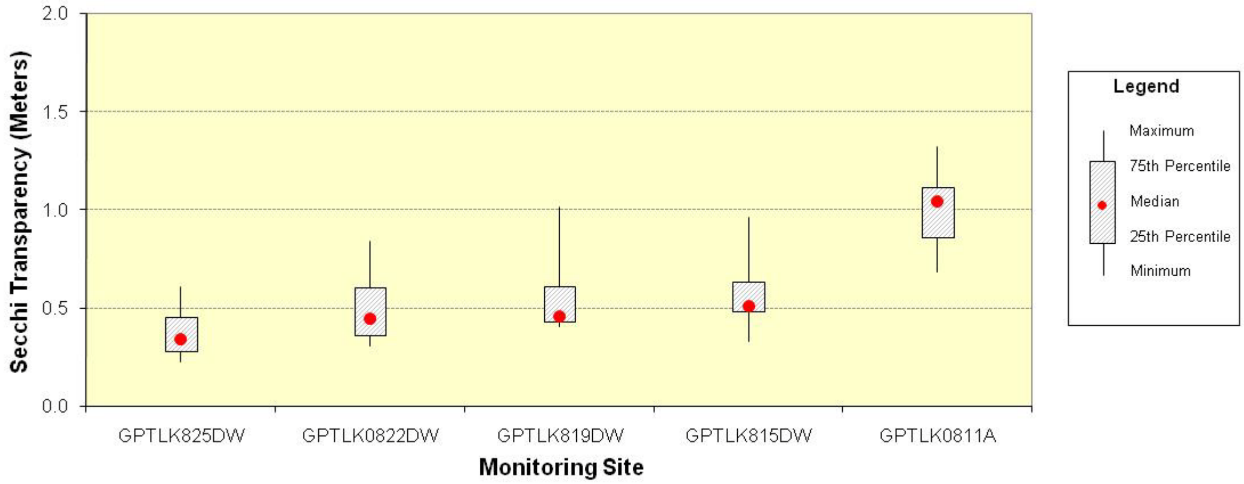


Figure 5-27. Box plot of Secchi transparencies measured in Lewis and Clark Lake during the 3-year period 2008 through 2010.

5.7.2.1.4.2 Turbidity

Monthly (i.e., June, July, August, and September) longitudinal contour plots were prepared from the depth-profile turbidity measurements taken at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW during 2010 (Plate 365, Plate 366, Plate 367, and Plate 368). As seen in the contour plots, turbidity levels measured in Lewis and Clark Lake during 2010 varied longitudinally from the dam to the reservoir's upstream reaches. This is attributed to the turbid conditions of the inflowing Missouri River which is impacted by the inflow of the Niobrara River 16 miles upstream of Lewis and Clark Lake.

5.7.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Lewis and Clark Lake during the summer were compared. Near-surface conditions were represented by samples collected within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 1-meter of the reservoir bottom. The compared samples were collected at the near-dam site GPTLK0811A during the 5-year period 2006 through 2010. During the period a total of 20 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon

(TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Plate 369). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for all assessed parameters except TKN. Parameters that were significantly lower in the near-bottom water of Lewis and Clark Lake included: water temperature ($p < 0.001$), dissolved oxygen ($p < 0.001$), pH ($p < 0.001$), and TOC ($p < 0.05$). Parameters that were significantly higher in the near-bottom water included: ORP ($p < 0.001$), alkalinity ($p < 0.01$), total ammonia ($p < 0.05$), and total phosphorus ($p < 0.05$).

5.7.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Lewis and Clark Lake were calculated from monitoring data collected during the 3-year period 2008 through 2010 (Table 5-23). The calculated TSI values indicate that the area near the dam (i.e., site GPTLK0811A) is eutrophic and the middle and upper reaches of the reservoir (i.e., sites GPTLK0819DW and GTPLK0825DW) are eutrophic to hypereutrophic.

Table 5-23. Mean Trophic State Index (TSI) values calculated for Lewis and Clark Lake. TSI values are based on monitoring at the identified three sites during the 3-year period 2008 through 2010.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
GPTLK0811A	60	53	67	60
GPTLK0819DW	69	57	69	65
GPTLK0825DW	76	59	68	67

Note: See Section 4.1.4 for discussion of TSI calculation.

5.7.2.1.7 Plankton Community

5.7.2.1.7.1 Phytoplankton

Phytoplankton grab samples collected from Lewis and Clark Lake at sites GPTLK0811A, GPTLK0819DW, and GPTLK0825DW during the spring and summer over the 5-year period 2006 through 2010 are summarized in Plate 370, Plate 371, and Plate 372. The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The relative abundance of phytoplankton in samples collected from Lewis and Clark Lake in May, July, and September 2010, based on biovolume, is shown in Figure 5-28. Diatoms (Bacillariophyta) are the most dominant phytoplankton group present in Lewis and Clark Lake. Major phytoplankton genera sampled in Lewis and Clark Lake during 2010 (i.e., genera comprising more than 10% of the total biovolume of at least one sample) included the Bacillariophyta *Asterionella*, *Aulacoseria*, *Cyclotella*, *and Fragilaria*; the Chlorophyta Chlamydomonas; and the Cryptophyta *Cryptomonas*. On one occasion (i.e., May 2008) an elevated level (14 ug/l) of the cyanobacteria toxin microcystin was monitored at site GPTLK0811A during the 5-year period 2006 through 2010 (Plate 350). Other than this one occasion, no levels of microcystin above 1 ug/l were monitored at sites GPTLK0811A, GPTLK0818DW, or GPTLK0825DW during the 3-year period 2008 through 2010.

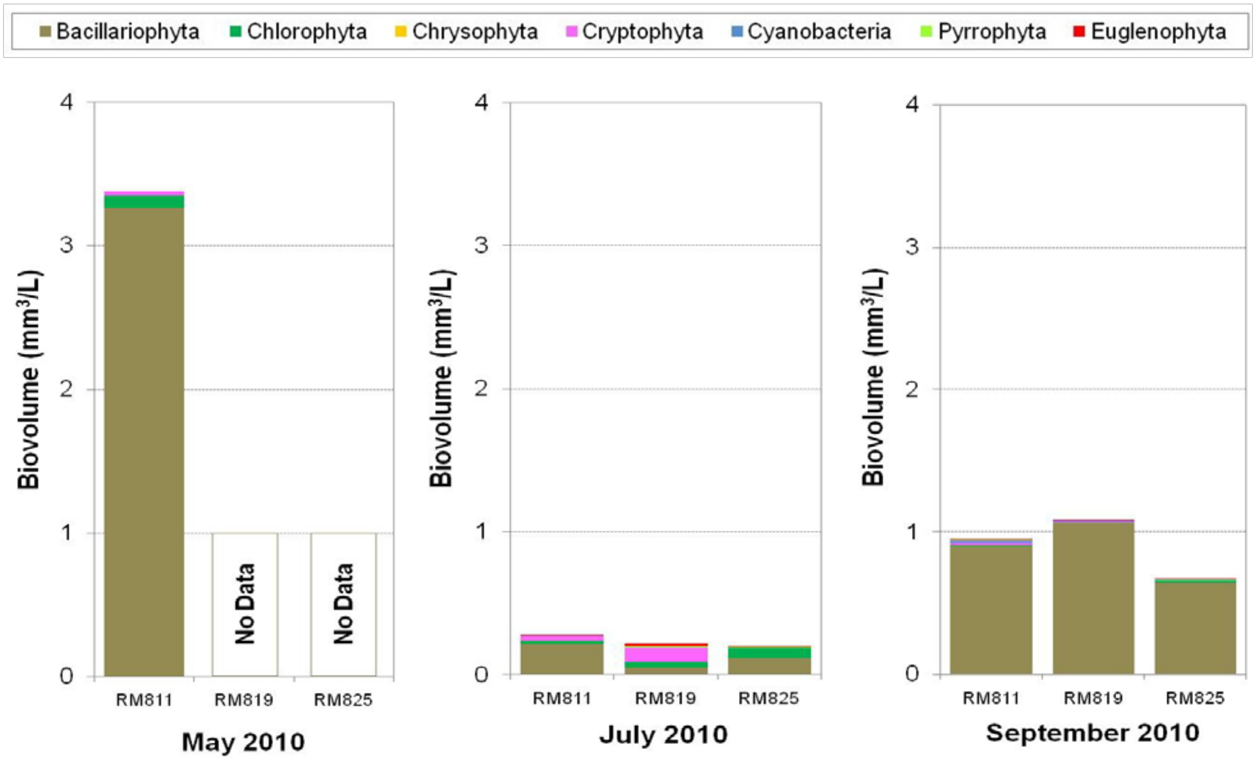


Figure 5-28. Relative abundance of phytoplankton in samples collected from Lewis and Clark Lake during 2010.

5.7.2.1.7.2 Zooplankton

Zooplankton vertical-tow samples were collected from Lewis and Clark Lake at sites GPTLK0811A, GPTLK0819DW, and GPTLK0825DW in May, July, and September of 2010 (Plate 373). The sampled zooplankton included four taxonomic groupings: Cladocerans, Copepods, Rotifers, and Ostracods. The relative abundance of these four taxonomic grouping in the zooplankton samples collected in 2010 is shown in Figure 5-29. Copepods were most abundant, followed by Cladocerans and rotifers. Only a few Ostracods were sampled in September at sites GPTLK0819DW and GPTLK0825DW. Major zooplankton species sampled in Lewis and Clark Lake during 2010 (i.e., species comprising more than 10% of the total biomass of at least one sample) included Cladocerans *Ceriodaphnia spp., Daphnia galeata, Daphnia retrocurva,* and *Diaphanosoma brachyurun*; Copepods *Acanthocyclops vernalis, Calanoid copepodid, Cyclopoid copepodid, Diacyclops, thomasi, Leptodiaptomus siciloides, Mesocyclops edax*, and *Tropocyclops prasinus*; and Rotifers *Brachionus calyciflorus, Keratella quadrata, Polyarthra vulgaris,* and *Synchaeta spp.* Dominant species (i.e., species comprising more than 25% of the total biomass of at least one sample) included Cladocerans *Daphnia retrocurva*; Copepods *Calanoid copepodid, Cyclopoid copepodid,* and *Mesocyclops edax.*

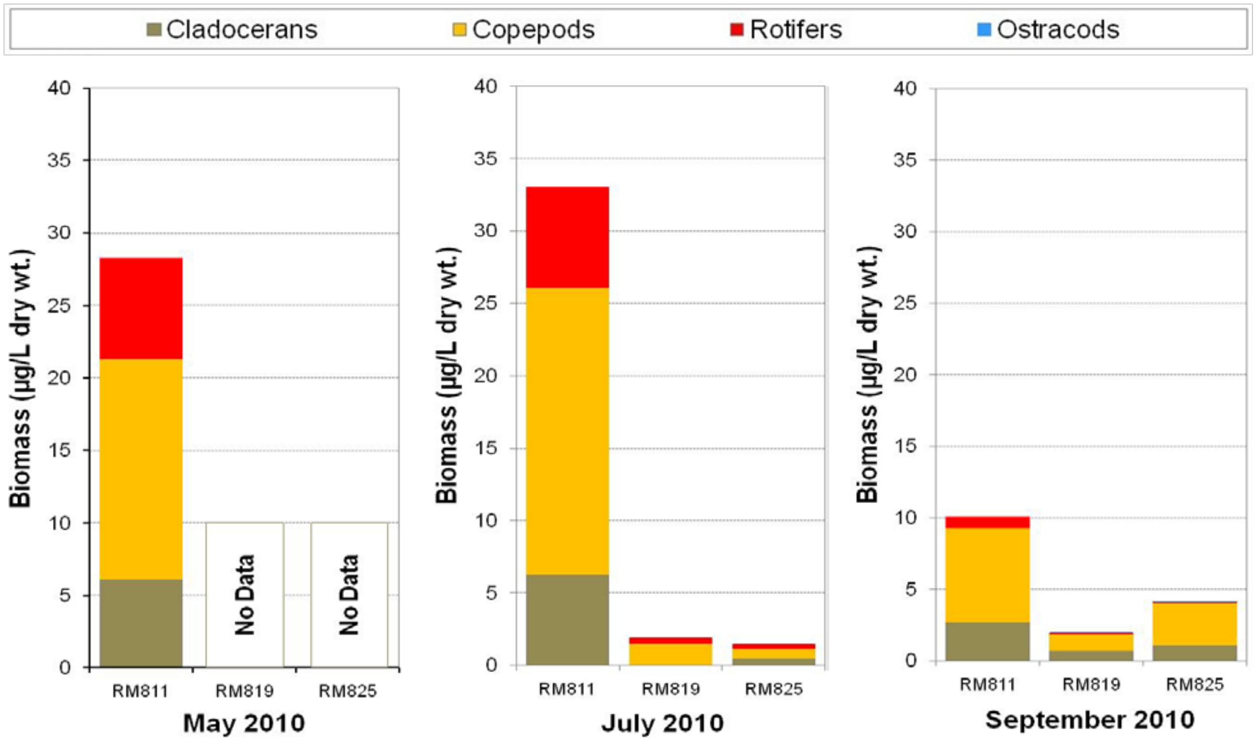


Figure 5-29. Relative abundance of zooplankton in samples collected from Lewis and Clark Lake during 2010**.**

5.7.2.1.8 Bacteria Monitoring at Swimming Beaches on Lewis and Clark Lake

During the 5-year period 2006 through 2010, bacteria samples were collected weekly from May through September at five swimming beaches located on Lewis and Clark Lake. The five swimming beaches where the bacteria samples were collected were: Weigand Recreation Area (site GPTLKBACT5), Gavins Point Recreation Area (site GPTLKBACT4), Lewis and Clark Recreation Area – Midway West Beach (site GPTLKBACT3) and Midway East Beach (GPTLKBACT2), and the Marina Sailing Boat Area (site GPTLKBACT1) (Figure 5-26). Table 5-24 summarizes the results of the bacteria sampling. The geometric means were calculated as running geometric means for five consecutive weekly bacteria samples and nondetects were set to 1. The bacteria sampling results were compared to following bacteria criteria for support of "full-body contact" recreation:

<u>Fecal Coliform:</u>
Bacteria of the fecal coliform group should not exceed a geometric mean of 200/100ml, nor equal or exceed 400/100ml, in more than 10% of the samples. These criteria are based on a minimum of five samples taken within a 30-day period.

<u>*E. coli*:</u>
E. coli bacteria should not exceed a geometric mean of 126/100ml. For increased confidence of the criteria, the geometric mean should be based on a minimum of five samples taken within a 30-day period. Single sample maximum allowable density for designated bathing beaches is 235/100ml.

Nebraska's recreational impairment assessment methodology (Section 4.1.6.2.2) defines criteria for "seasonal geomeans" for fecal coliform and *E. coli* bacteria. The calculated seasonal fecal coliform geomeans at GPTLKBACT5 for 2006, 2007, 2008, 2009, and 2010 are, respectively, 18, 23, 45, 12, and 25 cfu/100ml. The calculated seasonal *E. coli* geomeans at GPTLKBACT5 for 2006, 2007, 2008, 2009, and 2010 are, respectively, 13, 27, 37, 12, and 46. Based on these criteria, recreation was fully supported

at the Nebraska swimming beach on Lewis and Clark Lake during the 5-year period 2006 through 2010. It is noted that 13 percent of calculated *E. coli* geomeans at site GPTLKBACT5 exceeded the geometric mean criteria of 126/100ml (Table 5-24).

Table 5-24. Summary of weekly (May through September) bacteria sampling conducted at five swimming beaches on Lewis and Clark Lake over the 5-year period 2006 through 2010.

	Weigand Recreation Area (GPTLKBACT5)	Gavins Point Recreation Area (GPTLKBACT4)	Lewis & Clark Rec. Area Midway West (GPTLKBACT3)	Lewis & Clark Rec. Area Midway East (GPTLKBACT2)	Marina Sailing Boat Area (GPTLKBACT1)
Fecal Coliform Bacteria (cfu/100ml):					
Number of Samples	107	108	108	107	108
Mean	193	31	30	41	29
Median	18	12	8	8	6
Minimum	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	5,460	510	640	990	440
Percent of samples exceeding 400/100ml	7%	1%	2%	1%	1%
• **Geometric Mean**					
Number of Geomeans	88	88	88	88	88
Average	54	14	9	13	10
Median	21	12	7	9	7
Minimum	3	3	1	2	1
Maximum	682	48	30	37	129
Percent of Geomeans exceeding 200/100ml	7%	0%	0%	0%	0%
***E. coli* Bacteria (MPN/100ml)**					
Number of Samples	107	108	108	108	108
Mean	203	34	29	43	42
Median	18	12	6	6	5
Minimum	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	5,200	921	770	960	1,842
Percent of samples exceeding 235/100ml	17%	3%	3%	4%	3%
• **Geomean**					
Number of Geomeans	88	88	88	88	88
Average	54	13	7	13	9
Median	23	9	6	8	5
Minimum	3	2	n.d.	n.d.	2
Maximum	595	54	24	76	65
Percent of Geomeans exceeding 126/100ml	13%	0%	0%	0%	0%

n.d. = Not detected.
Note: Not detected values set to 1 to calculate mean and geometric mean.

5.7.2.1.9 Impairment of Designated Water Quality Beneficial Uses

Based on the State of Nebraska's impairment assessment methodology (Section 4.1.6.2), the water quality conditions monitored in Lewis and Clark Lake (i.e., chlorophyll *a* and total phosphorus) during

the 5-year period 2006 through 2010 indicate impairment of aquatic life due to nutrients. It is also noted that the estimated loss of 24.3 percent of the multi-purpose pool volume of Lewis and Clark Lake (Table 5-1) is approaching Nebraska's impairment identification criteria of 25 percent volume loss.

5.7.2.2 Water Quality Trends (1980 through 2010)

Water quality trends over the 31-year period of 1980 through 2010 were determined for Lewis and Clark Lake for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., site GPTLK0811A). Plate 374 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, Lewis and Clark Lake exhibited significant trends for Secchi depth (decreasing) and TSI (increasing). No significant trends were detected for total phosphorus and chlorophyll *a*. Over the 31-year period, the near-dam area of the reservoir has generally remained in a eutrophic state.

5.7.2.3 Creation of Emergent Sandbar Habitat (ESH) in the Headwaters of Lewis and Clark Lake and the Impacts on Water Quality

The U.S. Fish and Wildlife Service (USFWS) issued a Biological Opinion (BiOp) with recommendations for the U.S. Army Corps of Engineers' (Corps) operations of the Missouri River Mainstem System for protection and enhancement of threatened and endangered species. The BiOp found that the Corps' operations on the Missouri River were not likely to jeopardize the endangered interior least tern *(Sterna antillarum)* and threatened piping plover *(Charadrius melodus)* populations if the Reasonable and Prudent Alternative (RPA) set forth in the BiOp was implemented. The RPA includes recommendations for the mechanical creation and maintenance of Emergent Sandbar Habitat (ESH) as nesting habitat for these two species in terms of habitat acres per river mile. In accordance with the BiOp, the Corps is conducting ongoing efforts to create and/or reclaim a sufficient amount of ESH to stabilize, and eventually recover, interior least tern and piping plover populations along the Missouri River. The Missouri River reach from Gavins Point Dam upstream to the confluence of the Niobrara River, which includes Lewis and Clark Lake, has been identified as a priority reach for both the interior least tern and piping plover. A project to create and maintain ESH in the upper reaches of Lewis and Clark Lake is being implemented. Hydraulic dredging is being used to construct and maintain ESH complexes. The dredged material for building the sandbars is being obtained from the "delta" of deposited material at the inflow of the Missouri River to Lewis and Clark Lake.

5.7.2.3.1 Use of Lewis and Clark Lake and the Gavins Point Dam Tailwaters as Source Water for Drinking Water

Lewis and Clark Lake is utilized for source water by two rural water districts that provide public drinking water; Cedar Knox Rural Water District (CKRWD) and the Bon Homme-Yankton Rural Water District (BYRWD). The City of Yankton draws source water for drinking water use from the Missouri River approximately 5 miles downstream of Gavins Point Dam.

5.7.2.3.2 Potential Impact of ESH Creation in Lewis and Clark Lake on the Occurrence of Trihalomethanes (THMs) in Treated Drinking Water Supplies

The following discussion is taken from the Water Quality Office Report, "Creation of Emergent Sandbar Habitat (ESH) in the Headwaters of Lewis and Clark Lake and the Impacts on Water Quality" (USACE, 2009d).

Pursuant to the Federal Safe Drinking Water Act, both rural water districts and the City of Yankton monitor their source and treated drinking water for compliance with federal drinking water standards. This monitoring includes testing for trihalomethanes (THMs) and quarterly reporting of the results to the appropriate State authorities. The current MCL (maximum contaminant level) for total THMs is 80 μg/l. When testing indicates the MCL for total THMs is exceeded, the water suppliers must notify their users, as well as increase the frequency of testing, numbers of tests, and data reporting. The water suppliers expressed concerns to the Corps that the creation of the ESH in Lewis and Clark Lake degraded water quality to the degree that it impacted the quality of their treated drinking water. Specifically, there was concern that the dredging and sandbar construction increased the level of organic matter (THM precursors) in the reservoir, and this lead to the water suppliers exceeding water quality standards in their treated drinking water for THMs.

THMs include the compounds trichloromethane (chloroform), bromodichloromethane, dibromochloromethane, and tribromomethane (bromoform). THMs are formed when free chlorine reacts with THM precursors, most of which occur naturally. THM formation in treated drinking water occurs when source water containing THM precursors is chlorinated during treatment. THMs do not occur naturally, only when the source water is treated with disinfectants such as chlorine. The organic matter that supplies the carbon compounds that serve as THM precursors in surface waters is derived from allochthonous and autochthonous material. Allochthonous organic matter in watersheds is leached from soils or decaying vegetation and transported to surface waters. Autochthonous organic matter is produced through algal, macrophyte, and bacterial production in surface waters.

THMs commonly occur in the treated drinking water provided by the CKRWD, BYRWD, and the City of Yankton. Quarterly THM levels historically reported by the three treatment facilities indicate a strong seasonal trend with lower levels occurring in the winter and higher levels in the spring and summer. Treatment processes and retention time in the distribution system seemingly have a significant impact on the THM levels occurring at the treatment facilities.

The historical data from BYRWD indicates THM levels are consistently less than half of the 80 μg/l THM MCL standard. The small range of values indicates the treated water is not prone to extreme THM values, and reflects an ability of the BYRWD to effectively manage their water treatment process given the quality of the source water. THM concentrations in the BYRWD treated water were very low before and after ESH construction, so any increase in THM precursor levels in Lewis and Clark Lake that may have occurred from ESH construction or other seasonal sources were manageable with no non-compliance occurrences observed in the quarterly data. The quarterly data indicate the ESH construction in the upper reaches of Lewis and Clark Lake did not have an appreciable impact on the THM levels measured in BYRWD's treated water.

The reported THM levels at Yankton are notably higher than the levels reported for BYRWD. The THM levels at Yankton indicate the treatment facility has a greater vulnerability to high THM values and a greater risk for THM non-compliance events. The treatment process may have a major impact on the occurrence of THMs and non-compliance events at Yankton. The occurrence of high THM levels in Yankton's treated water do not appear to be correlated with the dredging that occurred to construct the ESH in the upper reaches of Lewis and Clark Lake. The level of THM precursors present in the Missouri River at the Yankton water intake appear to rise with the increase in organic matter attributable to spring and summer runoff and algal production in Lewis and Clark Lake.

The reported THM levels at CKRWD were also notably higher than the levels reported for BYRWD. The THM levels at CYRWD also indicate the treatment facility has a greater vulnerability to high THM values and a greater risk for THM non-compliance events. The treatment process may also have a major impact on the occurrence of THMs and non-compliance events at CKRWD. It is not clear

as to whether the ESH dredging in the upper reaches of Lewis and Clark Lake had a significant impact on the quarterly THM levels reported for CKRWD. THM levels reported in 2006 and 2007, when dredging occurred, do not indicate a noticeable impact as all quarterly results were within the historical range of normal seasonal variability. Quarterly reporting for 2008 indicated THM level greater than the historic maximum in the 4th quarter. This was during the period that dredging was completed on ESH complex 2.

Additional targeted water quality monitoring of treated water in the CKRWD distribution system during 2008 showed a strong seasonal trend in THM levels (i.e., low in early spring and early fall and high in the summer). THM levels in the CKRRWD distribution system were directly related to the distance from the treatment plant (i.e., locations the farthest away had the highest THM levels). Monitored THM levels associated with before and during ESH dredging periods did not indicate any impact; monitored THM levels were lower during ESH dredging.

Ambient water quality conditions monitored in Lewis and Clark Lake during 2008 were similar to conditions monitored in the past. Lewis and Clark Lake is in a eutrophic condition and experiences higher levels of algal growth during the summer. Targeted water quality monitoring was conducted in 2008 to evaluate the impact of the dredging to complete construction of ESH complex 2. Water quality monitoring of Lewis and Clark Lake was conducted immediately before and during dredging. The water quality monitoring included the parameter THM Formation Potential (THM-FP) which is a measure of the potential for THMs to form in water when under the influence of direct chlorination. Monitored levels of THM-FP (i.e., THM precursors) in Lewis and Clark Lake exhibited seasonality ("i.e., low levels in spring and fall and higher levels in the summer). This indicates that seasonal runoff and algal production (lacustrine and riverine) may be a primary source of THM precursors in Lewis and Clark Lake. THM-FP levels measured in Lewis and Clark Lake were appreciably lower than levels measured in eutrophic reservoirs in New York and Kentucky (Bukaveckas et.al., 2007 and Stepczuk et.al., 1998). Monitoring conducted immediately before and during the dredging to complete ESH complex 2 did not detect any significant impact of the dredging on the water quality of Lewis and Clark Lake. Monitored levels of THM-FP in the reservoir were lower during ESH dredging when compared to levels monitored immediately before dredging.

5.7.2.3.3 Trihalomethane Precursors Monitored at the Inflow, Headwaters, and Outflow of Lewis and Clark Lake during 2010

When subject to chlorination during water treatment, THM precursors form trihalomethanes which are known carcinogens. Major precursors affecting THM formation in chlorinated drinking water are believed to be humic and fulvic substances and simple low-molecular-weight organic compounds. To evaluate this concern, THM Formation Potential (THM-FP), total organic carbon (TOC), chlorophyll *a*, and true color were measured in samples collected at sites GTPNFMORR1, GTPLK0825DW, and GTPRRTW1. THM-FP measures the amount of THMs that are formed in a sample that is chlorinated for an extended period. TOC and color give an indication of the presence of low-molecular-weight organic compounds. Color in water may result from the presence of natural metallic ions (iron and manganese), humus and peat materials, plankton, weeds, and industrial wastes. "True color" is the color of water from which turbidity has been removed. True color can be indicative of the amount of dissolved humic substances present in water, and dissolved humic substances can be THM precursors. Dissolved low-molecular weight organic matter is believed to form THMs more readily than "residual" organic matter.

THM-FP, TOC, chlorophyll *a*, and true color levels monitored at the Lewis and Clark Lake inflow (Missouri River at Niobrara, NE – site GPTNFMOR1), headwaters (Lewis and Clark Lake – site GPTLK0825DW), and outflow (Gavins Point Dam tailwaters – site GPTRRTW1) during 2010 were plotted. Figure 5-30 plots THM-FP, TOC, chlorophyll *a*, and true color levels monitored at the three sites. With the possible exception of chlorophyll *a*, the measured levels of the four parameters at the three

sites were similar. Chlorophyll *a* levels were seemingly higher in the headwaters of Lewis and Clark Lake. The monitored levels of THM-FP, TOC, chlorophyll *a*, and true color in 2010 do not indicate that the construction of the Emergent Sandbar Habitat in the headwaters of Lewis and Clark Lake had a noticeable effect in raising THM precursor levels in the reservoir.

5.7.3 EXISTING WATER QUALITY CONDITIONS OF THE MISSOURI AND NIOBRARA RIVER INFLOWS TO LEWIS AND CLARK LAKE

5.7.3.1 Missouri River above the Confluence of the Niobrara River

5.7.3.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions of the Missouri River above the confluence of the Niobrara River are defined by the water quality conditions monitored in the outflow from Fort Randall Dam (site FTRPP1), in the Fort Randall Dam tailwaters (site FTRRRTW1), and in the Missouri River near Verdel, NE (site MORRR0851). Plate 321, Plate 322, Plate 348, and Plate 349 summarize water quality conditions monitored at these three sites over the 5-year period 2006 through 2010.

5.7.3.1.2 Nutrient Flux Conditions

The nutrient flux rates of the Missouri River above the confluence of the Niobrara River, over the 5-year period 2006 through 2010, were calculated based on near-surface water quality samples collected near Verdel, NE (i.e., site MORRR0851) and the instantaneous flow conditions at the time of sample collection (Table 5-25). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) are likely higher nearer the river bottom, near-surface grab samples likely under estimate the “true” water-column composite concentration for these constituents. Thus, the flux rates given for total phosphorus and total organic carbon in Table 5-25 should be considered minimum estimates with the actual flux rates being higher. The maximum flux rates for all the constituents are believed to be attributed to higher flows during maximum power production at Fort Randall Dam.

Table 5-25. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Verdel, NE (i.e., site MORRR0851) over the 5-year period 2006 through 2010.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	63	63	63	63	63	19	61
Mean	23,315	0.0390	0.3438	0.0355	0.276	0.0137	2.2685
Median	22,132	0.0201	0.2295	n.d.	0.0188	0.0092	1.8594
Minimum	3,012	n.d.	n.d.	n.d.	n.d.	n.d.	0.4245
Maximum	46,433	0.2527	1.2368	0.4270	0.2315	0.0546	6.0471

Note: Nondetectable values set to 0 for flux calculations.

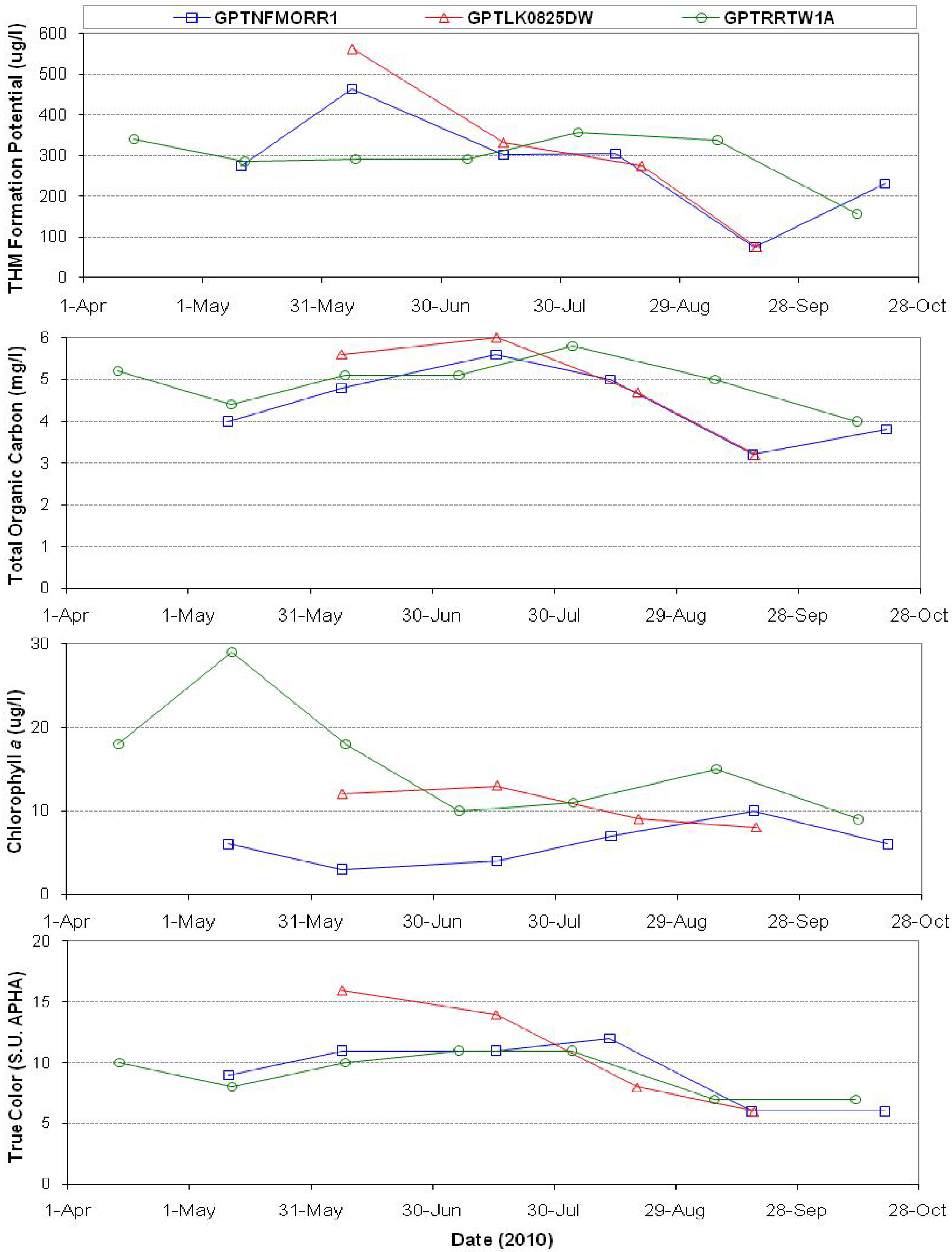


Figure 5-30. THM-FP, TOC, chlorophyll *a*, and true color levels measured at the inflow (GPTNFMORR1), headwaters (GPTLK0825DW), and outflow (GPTRRTW1) of Lewis and Clark Lake during 2010.

5.7.3.1.3 Mean Daily Discharge and Temperature

Mean daily discharge and water temperature of the Fort Randall Dam outflow were determined for the 5-year period 2006 through 2010. These are considered the water quality conditions of the Missouri River above the confluence of the Niobrara River. Plate 375, Plate 376, Plate 377, Plate 378, and Plate 379 plot annual mean daily water temperature and flow for the Fort Randall Dam discharge for the 5-year period.

5.7.3.2 Niobrara River

5.7.3.2.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions that were monitored in the Niobrara River at site GPTNFNIOR1 (Figure 5-26) during the 3-year period 2008 through 2010 are summarized in Plate 377. A review of these results indicated no significant water quality concerns.

5.7.3.2.2 Nutrient Flux Conditions

Nutrient flux rates of the Niobrara River, near the river's confluence with the Missouri River, were calculated based on near-surface water quality samples collected near Niobrara, NE (i.e., site GPTNFNIOR1) and the instantaneous flow conditions at the time of sample collection (Table 5-26). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) are likely higher nearer the river bottom, near-surface grab samples likely under estimate the "true" water-column composite concentration for these constituents. Thus, the flux rates given for total phosphorus and total organic carbon in Table 5-26 should be considered minimum estimates with the actual flux rates being higher. The maximum nutrient flux rates are attributed to greater nonpoint-source nutrient loadings associated with runoff conditions.

Table 5-26. Summary of nutrient flux rates (kg/sec) calculated for the Niobrara River near Niobrara, NE (i.e., site GPTNFNIOR1) for the 3-year period 2008 through 2010.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	19	19	19	19	19	17	19
Mean	2,219	0.0021	0.0758	0.0429	0.0189	0.0035	0.3427
Median	1,950	0.0019	0.0603	0.0297	0.0119	0.0036	0.2789
Minimum	753	n.d.	0.0189	n.d.	0.0043	n.d.	0.0746
Maximum	3,950	0.0106	0.1988	0.1611	0.0511	0.0101	0.8652

Note: Non-detect values set to 0 for flux calculations.

5.7.3.2.3 Continuous Water Temperature Monitoring of the Niobrara River at USGS Gage Site 06465500 near Verdel, Nebraska

Through an agreement with the USGS, a water temperature monitoring probe was added to the USGS's gage (06465500) on the Niobrara River near Verdel, NE (i.e., near site GTPNFNIOR1). Beginning in April 2005, hourly water temperature measurements were recorded at the site. Plate 381, Plate 382, Plate 383, Plate 384, and Plate 385, respectively, plot mean daily water temperature and river discharge determined for 2006, 2007, 2008, 2009, and 2010.

5.7.3.3 <u>Missouri River below the Confluence of the Niobrara River</u>

5.7.3.3.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions that were monitored in the Missouri River near Running Water, SD at site GPTNFMORR1 (Figure 5-26) during 2010 are summarized in Plate 386. A review of these results indicated no significant water quality concerns.

5.7.3.3.2 Vertical Water Quality Variation in the Missouri River

Depth discrete water quality monitoring of the Missouri River at site GPTNFMORR1 was initiated in 2010. Depth-profiles in ½-meter increments were measured for water temperature, dissolved oxygen, pH, conductivity, ORP, turbidity, and chlorophyll *a*. Near-surface and near-bottom grab samples were collected from the thalweg of the river at site GPTNFMORR1. The near-surface sample was collected by dipping a plastic churn bucket just below the water surface. The near-bottom sample was collected by lowering a finned-Van Dorn sampler to within ½-meter of the river bottom while the boat was drifting in the current.

5.7.3.3.2.1 Depth-Profile Plots

Depth-profile plots were constructed for water temperature, dissolved oxygen, pH, conductivity, turbidity, and chlorophyll *a* (Plate 387). The depth-profile plots indicate minimal variation in the six parameters with depth. The plots do indicate appreciable differences for selected parameters between monitoring dates.

5.7.3.3.2.2 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected at site GPTNFMORR1 during 2010 were compared. Four paired samples (June, July, August, and September) were collected during 2010. Box plots were constructed to display the distribution of the paired near-surface and near-bottom samples for selected non-particulate-associated (i.e., water temperature, total dissolved solid, dissolved sulfate, and dissolved phosphorus) and particulate-associated (i.e., total suspended solids, total suspended sediment, total Kjeldahl nitrogen, total phosphorus, and total organic carbon) constituents (Plate 388). Anecdotally, the box plots indicate little observable depth variation in the non-particulate- associated constituents. The box plots of the particulate-associated constituents indicate the maximum values for all these constituents, except TKN, were associated with the bottom samples. A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were not found to be significantly different for any parameter. It is noted that the small sample size limited the power of the applied statistical method to test for significant differences, and more testing will be done in the future as additional samples are collected.

The near-surface and near-bottom concentrations of the particulate-associated constituents total phosphorus, total Kjeldahl nitrogen, total suspended sediment, total suspended solids, and total organic carbon measured at site FTPNFMORR1 were plotted against the flow of the Missouri River at the time of sampling (Plate 389). Near-bottom concentrations of the particulate-associated constituents were higher than the near-surface levels during most instances. In one case, the measured near-surface concentration of TKN was higher than the paired near-bottom measured concentration.

5.7.3.3.3 Nutrient Flux Conditions

Nutrient flux rates of the Missouri River downstream of the Niobrara River and upstream of Lewis and Clark Lake were calculated based on near-surface water quality samples collected from the Missouri River near Running Water, SD (i.e., site GPTNFNIOR1) and the instantaneous flow conditions at the time of sample collection (Table 5-27). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) are likely higher nearer the river bottom, near-surface grab samples likely under estimate the "true" water-column composite concentration for these constituents. Thus, the flux rates given for total phosphorus and total organic carbon in Table 5-27 should be considered minimum estimates with the actual flux rates being higher. Plate 387, Plate 388, and Plate 389 compare near-surface and near-bottom water quality conditions monitored at site GPTNFMORR1. The maximum nutrient flux rates are attributed to greater nonpoint-source nutrient loadings associated with runoff conditions.

Table 5-27. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Running Water, SD (i.e., site GPTNFMORR1) for 2009 and 2010.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	16	16	16	16	16	12	16
Mean	31,499	0.0297	0.5691	0.3147	0.0742	0.0385	3.5053
Median	28,948	0.0253	0.5166	0.2613	0.0725	0.0309	3.0197
Minimum	15,562	n.d.	0.1309	n.d.	n.d.	n.d.	1.6913
Maximum	50,456	0.1257	1.4104	1.1852	0.1541	0.1083	6.4505

Note: Non-detect values set to 0 for flux calculations.

5.7.3.3.4 Mean Daily Discharge and Temperature

The estimated mean daily discharge and temperature of the annual Missouri River inflow to Lewis and Clark Lake for 2006 through 2010 are plotted in Plate 390, Plate 391, Plate 392, Plate 393, and Plate 394. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, NE at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites.

5.7.4 WATER QUALITY AT THE GAVINS POINT POWERPLANT

5.7.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 395 and Plate 396 summarize the water quality conditions that were monitored on water discharged through Gavins Point Dam during the 5-year period 2006 through 2010. A review of these results indicated no major water quality concerns.

5.7.4.2 Impairment of Designated Water Quality Beneficial Uses

Based on the States of Nebraska and South Dakota impairment assessment methodologies (Sections 4.1.6.2 and 4.1.6.4), the water quality conditions monitored in Gavins Point Dam discharge during the 5-year period 2006 through 2010 did not indicate impairment of any designated water quality beneficial uses of the downstream Missouri River.

5.7.4.3 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Semiannual time-series plots for temperature, dissolved oxygen, and powerplant discharge monitored at the Gavins Point powerplant during the 5-year period 2006 through 2010 were constructed (Plate 397 - Plate 416). Water temperatures showed seasonal warming and cooling through each calendar year. Dissolved oxygen levels remained relatively high and stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall. Except for a few occasions in the spring, the lowest dissolved oxygen levels occurred during mid- to late July. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. The lower dissolved oxygen concentrations in July may be associated with degradation in the hypolimnion when limited thermal stratification is able to become established. There appeared to be little correlation between discharge rates and measured water temperature and dissolved oxygen concentrations.

5.7.4.4 Comparison of Monitored Inflow and Outflow Temperatures of the Missouri River at Lewis and Clark Lake

Plate 417, Plate 418, Plate 419, Plate 420, and Plate 421 annually plot the mean daily water temperatures estimated for the Missouri River inflow to Lewis and Clark Lake and monitored at the Gavins Point Dam powerplant (site GTPPP1) for the 5-year period 2006 through 2010. Inflow temperatures of the Missouri River to Lewis and Clark Lake tend to be at little cooler than the outflow temperatures of Gavins Point Dam during the spring to mid-summer. Outflow temperatures of the Gavins Point Dam discharge tend to be a little cooler than the Missouri River inflow temperatures in the late-summer and fall.

5.7.4.5 Nutrient Flux Conditions of the Gavins Point Dam Discharge to the Missouri River

Nutrient flux rates for the Gavins Point Dam discharge to the Missouri River over the 5-year period 2006 through 2010 were calculated based on samples taken from the Gavins Point powerplant (i.e. site GPTPP1) and the total dam discharge at the time of sample collection (Table 5-28). The samples collected in the powerplant are taken from the raw water supply line and are believed to be unbiased regarding particulate-associated constituents. Therefore, the flux rates calculated for the Gavins Point Dam discharge give an unbiased estimate of the flux rates for all the constituents, including total phosphorus and total organic carbon. The maximum flux rates for all the constituents are believed to be attributed to higher dam discharges.

Table 5-28. Summary of nutrient flux rates (kg/sec) calculated for the Gavins Point Dam total discharge to the Missouri River (i.e., site GTPPP1) during January through December over the 5-year period 2006 through 2010.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	50	50	50	50	50	47	49
Mean	19,249	0.0232	0.3179	0.0631	0.0317	0.0155	2.0860
Median	17,036	0.0051	0.2724	0.0547	0.0217	0.0096	1.6170
Minimum	8,000	n.d.	n.d.	n.d.	n.d.	n.d.	0.7136
Maximum	49,065	0.1620	0.9497	0.2898	0.1835	0.0925	7.1371

Note: Nondetectable values set to 0 for flux calculations.

5.8 COMPARISON OF EXISTING WATER QUALITY CONDITIONS AT THE MAINSTEM SYSTEM RESERVOIRS

During 5-year period of 2006 through 2010, conditions in the upper Missouri River basin were characterized by severe drought early in the period and more "normal" to above normal precipitation and runoff later in the period. During this period, Mainstem System reservoirs experienced historic low pool elevations and water in storage dropped to 46 percent of the Mainstem System storage capacity in February 2007. By the end of 2010 storage had recovered to 78 percent of the Mainstem System storage capacity. During the 5-year period reduced pool levels and reservoir volumes were especially pronounced at the upper three Mainstem System reservoirs: Fort Peck, Garrison, and Oahe. Drought induced reduction in reservoir volumes could reasonably be expected to have water quality ramifications due to reductions in the pollution assimilative capacity of the reservoirs and exposure of previously flooded sediments. The final impact of the existing drought on water quality conditions at the Mainstem System reservoirs is still to be determined; however, monitoring of existing water quality conditions does not indicate major concerns other than the maintenance of coldwater fishery habitat in Lake Sakakawea during the drought-induced low reservoir pool elevations.

5.8.1 IMPAIRMENT OF DESIGNATED WATER QUALITY DEPENDENT BENEFICIAL USES

The attainment of water quality standards at the Mainstem System Projects, based on water quality conditions monitored over the 5-year period 2006 to 2010 by the District, is summarized in Table 5-29. Water quality standards attainment was defined as whether the designated beneficial uses in State water quality standards were impaired based on the monitored water quality conditions and defined State impairment assessment criteria. It is noted that the "official" determination of whether designated beneficial uses are impaired, pursuant to the Federal Clean Water Act, is made by the States pursuant to their Section 305(b) and Section 303(d) assessments (See Table 1-3). As shown in Table 1-3, the States of Montana, North Dakota, South Dakota, and Nebraska currently list Fort Peck Lake, Lake Sakakawea, Lake Sharpe, and Lewis and Clark Lake, respectively, as impaired. The District defers to Montana's assessment of drinking water impairment, as the District does not monitor or review source water quality conditions of public drinking water facilities utilizing Fort Peck Lake as source water. The District's monitoring of Lake Sakakawea indicates a concern regarding the maintenance of coldwater habitat in the reservoir during low pool elevations. The Coldwater Permanent Fish Life Propagation use designated to Lake Sharpe is not being attained due to warm water temperatures. Consideration should be given to reclassify the reservoir for a Warmwater Permanent Fish Life Propagation use based on a use attainability assessment of "natural conditions" regarding ambient water temperatures. Based on the State of Nebraska's impairment assessment methodology, the water quality conditions monitored in Lewis and Clark Lake indicate impairment of aquatic life due to nutrients.

Table 5-29. Summary of impairment of designated beneficial uses (i.e., water quality standards attainment) based on existing water quality conditions monitored at the Mainstem System projects over the 5-year period 2006 through 2010.

(Note: "Official" identification of impaired water bodies is given in State prepared Section 303(d) assessments – see **Table 1-3**.)

	Recreation[1]	**Coldwater Aquatic Life**	**Warmwater Aquatic Life**	**Domestic Water Supply**	**Agricultural Water Supply**	**Industrial Water Supply**
Fort Peck Lake	Unknown	Not Assigned[2]	Full Support	Full Support[9]	Full Support	Full Support
Fort Peck Dam Tailwaters	Unknown	Full Support	Full Support	Full Support	Full Support	Full Support
Lake Sakakawea	Unknown	Full Support[3]	Full Support	Full Support	Full Support	Full Support
Garrison Dam Tailwaters	Unknown	Threatened[4]	Threatened[4]	Full Support	Full Support	Full Support
Lake Oahe	Unknown	Full Support	Full Support	Full Support	Full Support	Full Support
Oahe Dam Tailwaters	Unknown	Impaired[5]	Full Support	Full Support	Full Support	Full Support
Lake Sharpe	Unknown	Impaired[6]	Full Support	Full Support	Full Support	Full Support
Big Bend Dam Tailwaters	Unknown	Not Assigned	Full Support	Full Support	Full Support	Full Support
Lake Francis Case	Unknown	Not Assigned	Full Support	Full Support	Full Support	Full Support
Fort Randall Dam Tailwaters	Unknown	Not Assigned	Threatened[4]	Full Support	Full Support	Full Support
Lewis and Clark Lake	Full Support	Not Assigned	Impaired[7] Threatened[8]	Full Support	Full Support	Full Support
Gavins Point Dam Tailwaters	Unknown	Not Assigned	Full Support	Full Support	Full Support	Full Support

(1) Water quality standards attainment for recreation is based on assessment of collected bacteria data.

(2) The State of Montana has not designated a coldwater aquatic life use to Fort Peck Lake. A coldwater fishery and associated aquatic life do exist in Fort Peck Lake and seemingly are an existing use. Monitored water quality conditions indicate that it is currently fully supported.

(3) Coldwater aquatic life in Lake Sakakawea can seemingly be impaired by warm water temperatures and low dissolved oxygen levels during late summer. This is believed a result of reduced hypolimnetic volume associated with low pool elevations and the degradation of dissolved oxygen in the hypolimnion.

(4) Aquatic life uses in the Garrison and Fort Randall Dam tailwaters may be threatened by low dissolved oxygen levels during late summer. Water discharged from both dams is drawn from the bottom of respective reservoirs. The reservoirs thermally stratify during the summer and the lower depths of the hypolimnion experience dissolved oxygen degradation as the summer progresses.

(5) Lake Oahe thermally stratifies in the summer and coldwater aquatic life is supported in the reservoir's hypolimnion. However, the power tunnel portals at Oahe Dam are located about 114 feet above the bottom of the reservoir and dam discharges during the summer commonly draw warmer water from the metalimnion and epilimnion – especially when pool elevations are low. Thus, water temperatures in the Oahe Dam tailwaters are not supportive of coldwater aquatic life during mid- to late-summer.

(6) Lake Sharpe generally does not exhibit significant thermal stratification in the summer; therefore, a coldwater hypolimnion does not usually form. The lack of significant summer thermal stratification at the reservoir is attributed to its relative shallowness and the high discharges released through Big Bend Dam associated with its operation to meet peak power demands. Due to the lack of significant summer thermal stratification, ambient water temperatures in Lake Sharpe are not cold enough to support coldwater permanent fish life propagation, as defined by State water quality criteria. Consideration should be given to reclassify Lake Sharpe for a warmwater permanent fish life propagation use based on a use attainability assessment of "natural conditions" regarding ambient water temperature.

(7) Warmwater aquatic life (i.e., aesthetics) is impaired due to nutrients based on monitored total phosphorus and chlorophyll *a* levels.

(8) Warmwater aquatic life is seemingly threatened by sedimentation of Lewis and Clark Lake as the volume loss from the "as-built" multiple use pool is approaching 25 percent (i.e., 24.3%).

(9) The District's monitoring of ambient water quality conditions in Fort Peck Lake does not indicate impairment of domestic water supply. The District however defers to Montana's assessment of drinking water as impaired, as the District does not monitor or review source water quality conditions of public drinking water facilities utilizing Fort Peck Lake as source water.

5.8.2 GENERAL WATER QUALITY CONDITIONS IN THE MAINSTEM SYSTEM RESERVOIRS

Table 5-30 summarizes general water quality conditions at the Mainstem System reservoirs based on the water quality monitoring conducted over the 5-year period 2006 through 2010. The four largest reservoirs (i.e., Fort Peck, Garrison, Oahe, and Fort Randall) exhibit characteristics typical of dimictic lakes (Wetzel, 2001). The four reservoirs exhibit summer and winter thermal stratification separated by periods of complete mixing during the spring and fall turnover periods. A large quiescent hypolimnion forms during the summer in the three larger reservoirs (i.e., Fort Peck, Garrison, and Oahe) with a smaller hypolimnion forming in Fort Randall. The formation of a smaller hypolimnion in Fort Randall Reservoir, as compared to the three other reservoirs, is attributed to its lesser maximum depth and volume. Due to their shallower depths, Big Bend and Gavins Point Reservoirs appears to be discontinuous polymixic, with periods of summer thermal stratification forming and breaking down as climatic factors change. Wetzel (2001) identifies lakes as discontinuous cold polymictic if they are ice-covered part of the year and ice-free above 4°C during the warm season, and exhibit thermal stratification during the warm period for periods of several days to weeks but with irregular interruption by mixing. Big Bend Reservoir does not typically exhibit prolonged summer thermal stratification due to the high discharge rates that occur through Big Bend Dam for power production. Moderate hypolimnetic dissolved oxygen degradation regularly occurs in Garrison and Fort Randall Reservoirs. Only minor hypolimnetic dissolved oxygen degradation appears to occur in Fort Peck, Oahe, and Big Bend Reservoirs. Significant dissolved oxygen degradation can occur in Gavins Point Reservoir during the summer when thermal stratification persists. Water quality conditions of summer discharges from Garrison and Fort Randall Dams are highly correlated to dam discharge rates. This high degree of correlation of summer water quality conditions of discharged water with the dam discharge rate is not evident at the other four Mainstem System dams. The high degree of correlation at Garrison and Fort Randall Dams is attributed to each dam having a near-bottom withdrawal from their impounded reservoirs. The vertical extent of the withdrawal zone in these two reservoirs is dependent on the dam discharge rate. The lacustrine areas of the five upper reservoirs all appear to be mesotrophic, with only Gavins Point being in a eutrophic condition. The prevalence of major phytoplankton groups is similar in all six Mainstem System reservoirs, with diatoms being the most prevalent group. Copepods are the most prevalent zooplankton present in Fort Peck, Oahe, Big Bend and Gavins Point, while Cladocerans are the most prevalent zooplankton in Garrison and Fort Randall.

Table 5-30. Summary of general water quality conditions monitored at the Mainstem System reservoirs over the 5-year period 2006 through 2010. (Note: Record low pool levels occurred during the 5-year period due to severe drought in the western United States where the reservoirs are located.)

	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point
Maximum reservoir depth near the dam when pool elevation is at the top of Carryover Multiple Use Zone.	204 ft	168 ft	193 ft	92 ft	123 ft	68 ft
Minimum and maximum hourly pool elevation recorded during the 5-year period 2006 through 2010.	2196.2 ft 2235.9 ft	1806.6 ft 1851.4 ft	1570.2 ft 1617.9 ft	1419.4 1421.4	1336.5 ft 1368.1 ft	1205.8 ft 1209.7 ft
Maximum reservoir depth near the dam at the minimum and maximum pool elevation recorded during the 5-year period 2006 through 2010.	166 ft 206 ft	137 ft 181 ft	155 ft 203 ft	89 ft 91 ft	110 ft 141 ft	66 ft 70 ft
Extent of hypolimnion formed during summer thermal stratification period	Large (Plates 4-8)	Large (Plates 73-77)	Large (Plates 164-168)	Very Small (Plates 232-235)	Moderate (Plates 292-296)	Small (Plates 355-358)
Extent of dissolved oxygen degradation in the hypolimnion just prior to "fall turnover" of the reservoir	Minor (Plates 10-14)	Moderate (Plates 79-83)	Minor (Plates 170-174)	Minor (Plates 237-240)	Moderate (Plates 298-302)	Moderate (Plates 360-363)
Correlation of dam discharge water quality conditions to dam discharge rates during the summer	Low (Plates 39-58)	High (Plates 111-140)	Low (Plates 202-221)	Low (Plates 260-279)	High (Plates 323-342)	Low (Plates 397-416)
Lake trophic status[(1)]	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Eutrophic
Average TSI score[(2)]	48	50	47	50	50	60
Most prevalent phytoplankton group sampled[(3)]	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta
Percent of samples where Cyanobacteria was the most prevalent phytoplankton group based on collected biovolume[(3)]	17%	4%	4%	4%	0%	0%
Most prevalent zooplankton group sampled[(4)]	Copepods	Cladocerans	Copepods	Copepods	Cladocerans	Copepods

(1) Based on near-dam water quality conditions in the reservoir.
(2) TSI = Trophic State Index (see text for explanation). Based on near-dam water quality conditions in the reservoir.
(3) Based on phytoplankton biovolume samples collected near the dam of each reservoir.
(4) Based on zooplankton biomass samples collected near the dam of each reservoir.

6 LOWER MISSOURI RIVER: GAVINS POINT DAM TO RULO, NE

6.1 CHANNEL CHARACTERISTICS AND TRIBUTARIES

The Missouri River between Gavins Point Dam (RM 811) and Rulo, NE (RM498) flows in an east-southeasterly to south-southeasterly direction. Major tributaries to the Missouri River below Gavins Point Dam, moving downstream, include: James River (South Dakota) at RM 801, Vermillion River (South Dakota) at RM 772, Big Sioux River (South Dakota and Iowa) at RM 734, Floyd River (Iowa) at RM 731, Little Sioux River (Iowa) at RM 669, Soldier River (Iowa) at RM664, Boyer River (Iowa) at RM 635, Platte River (Nebraska) at RM 595, Nishnabotna River (Iowa) at RM 542, and Tarkio River (Missouri) at RM 508. Extensive bed degradation has occurred in the upper areas of this Missouri River reach because river sediment is captured above Gavins Point Dam. Another factor is the substantial Missouri River channel shortening that occurred as part of the downstream Missouri River Bank Stabilization and Navigation Project. Gradual armoring of the riverbed has reduced the rate of channel degradation. Since 1965, approximately 10 feet of stage reduction has occurred for a discharge of 30,000 cfs in the Sioux City, IA area. During this period channel degradation of the Missouri River downstream in the Omaha, NE (RM 615.9) area has been non-existent. This reach of the Missouri River can be separated into three distinct sub reaches: the Missouri River National Recreational River, Kensler's Bend, and the Missouri River Navigation Channel reaches.

6.1.1 MISSOURI RIVER NATIONAL RECREATION RIVER REACH

The 59-mile reach of the Missouri River downstream of Gavins Point Dam starting at RM 811 down to Ponca, NE (RM 752) has been designated a National Recreational River under the Federal Wild and Scenic Rivers Act. This reach of the river has not been channelized by construction of dikes and revetments, and has a meandering channel with many chutes, backwater marshes, sandbars, islands, and variable current velocities. Snags and deep pools are also common. Although this portion of the river includes some bank stabilization structures, the river remains fairly wide. Bank erosion rates since the closure of Gavins Point Dam in 1956 have averaged 132 acres per year between Gavins Point Dam and Ponca, compared to a pre-dam rate of 202 acres per year. The rate of erosion had been declining since 1975 and then dramatically increased during the high flow years of 1995 through 1997.

6.1.2 KENSLER'S BEND REACH

The Kensler's Bend reach of the Missouri River extends from Ponca, Nebraska (RM 752) to above Sioux City, IA (RM 735). The Missouri River banks have been stabilized with dikes and revetments through this reach, but it has not been channelized.

6.1.3 MISSOURI RIVER NAVIGATION CHANNEL REACH

The reach of the Missouri River from the end of the Kensler's Bend reach (RM 735) to Rulo, NE (RM 498) has been modified over its entire length by an intricate system of dikes and revetments designed to provide a continuous navigation channel without the use of locks and dams. This reach is managed by the Corps under the Missouri River Bank Stabilization and Navigation Project. In addition to the primary authorization to maintain a navigation channel (9 ft deep by 300 ft wide) downstream from Sioux City, IA to the mouth of the Missouri River, there are authorizations to stabilize the river's banks.

6.2 FLOW REGULATION

Releases from Gavins Point Dam follow the same pattern as those from Fort Randall Dam because there is little active storage in Lewis and Clark Lake. Releases from both dams are based on the amount of water in Mainstem System storage, which governs how much water will be released to meet service demands in the portion of the lower Missouri River from Sioux City, IA to St. Louis, MO. Constraints for flood control, threatened and endangered bird nesting, and fish spawning also are factors governing releases. Releases from Gavins Point Dam generally fall into three categories: navigation, flood evacuation, and non-navigation releases.

6.2.1 MAINSTEM SYSTEM SERVICE LEVEL

To facilitate appropriate application of multipurpose regulation criteria to the Mainstem System, a numeric "service level" has been adopted since the Mainstem System was first filled in 1967. Quantitatively, a full service level approximates the water release rate necessary to achieve a normal 8-month navigation season with average downstream tributary flow contributions. For "full-service" and "minimum service" levels, the numeric service level values are, 35,000 cfs (cubic feet per second) and 29,000 cfs, respectively. This service level is used for selection of appropriate flow target values at previously established downstream control locations on the Missouri River. There are four flow target locations selected below Gavins Point Dam to assure that the Missouri River has adequate water available for the entire downstream reach to achieve regulation objectives. The four flow target locations and their flow target discharge deviation from service levels are: Sioux City (-4,000 cfs); Omaha (-4,000 cfs); Nebraska City (+2,000 cfs); and Kansas City (+6,000 cfs). A full-service level of 35,0000 cfs results in target discharges of 31,000 cfs at Sioux City and Omaha; 37,000 cfs at Nebraska City; and 41,000 cfs at Kansas City. Similarly, a minimum-service level of 29,000 cfs results in target values of 6,000 cfs less than the full-service levels at the four target locations. The relation of service levels to the volume of water in Mainstem System storage is as follows:

Date	Water in Mainstem System Storage (MAF)	Service Level (cfs)
March 15	54.5 or more*	35,000 (full-service)
March 15	31.0 to 49.0*	29,000 (minimum-service)
March 15	31.0 or less	No Service
July 1	57.0 or more*	35,000 (full-service)
July 1	50.5 or less*	29,000 (minimum-service)
* Straight-line interpolation defines intermediate service levels between full and minimum service.		

The length of the navigation season is determined by the volume of water in storage as follows:

Date	Water in Mainstem System Storage (MAF)	Season Closure Date at Mouth of Missouri River
March 15	Less than 31.0	No season
July 1	51.5 or more*	December 1 (8-month season)
July 1	41.0 to 46.8*	November 1 (7-month season)
July 1	36.5 or less*	October 1 (6-month season)
* Straight-line interpolation defines intermediate closure date between given values.		

6.2.2 HISTORIC FLOW RELEASES

In the navigation season, which generally runs from April 1 through November 30, releases from Gavins Point Dam are generally 25,000 to 35,000 cfs. In the winter, releases are in the 10,000- to 20,000-

cfs range. In wet years with above-normal upstream inflows, releases are higher to evacuate flood control storage space in upstream reservoirs. Maximum winter releases are generally kept below 24,000 cfs to minimize downstream flooding problems caused by ice jams in the lower river. During the 1987 to 1993 and the 2000 to 2008 droughts, non-navigation releases were generally in the 8,000- to 9,000- cfs range immediately following the end and preceding the start of the navigation season. During cold weather, releases were increased up to 15,000 cfs, but generally averaged 12,000 cfs over the 3-month winter period from December through February.

6.2.3 FLOW RELEASES FOR WATER QUALITY MANAGEMENT

Generally, Mainstem System release levels necessary to meet downstream water supply purposes exceed the minimum release levels necessary to meet minimum downstream water quality requirements. Tentative flow requirements for satisfactory water quality were first established by the U.S. Public Health Service and presented in the 1951 Missouri Basin Inter-Agency Committee Report on Adequacy of Flows in the Missouri River. These requirements were used in Mainstem System regulation until revisions were made in 1969 by the Federal Water Pollution Control Administration. The Missouri River minimum daily flow requirements for water quality (i.e., dissolved oxygen) that are given below were initially established by the Federal Water Pollution Control Administration in 1969. They were reaffirmed by the U.S. Environmental Protection Agency in 1974 after consideration of: 1) the current status of PL 92-500 programs for managing both point and non-point sources discharging into the river, and 2) the satisfactory adherence to the dissolved-oxygen concentration of 5.0 mg/l. The minimum daily flow requirements listed below are used for Mainstem System regulation purposes.

Location	Dec, Jan, Feb	Mar, Apr	May	Jun, Jul, Aug, Sep	Oct, Nov
Sioux City, IA	1,800 cfs	1,370 cfs	1,800 cfs	3,000 cfs	1,350 cfs
Omaha, NE	4,500 cfs	3,375 cfs	4,500 cfs	7,500 cfs	3,375 cfs
Kansas City, MO	5,400 cfs	4,050 cfs	5,400 cfs	9,000 cfs	4,050 cfs

Low flows in the Missouri River downstream from Gavins Point Dam may affect the ability of powerplants on this reach to meet National Pollutant Discharge Elimination System (NPDES) permit thermal limits for discharging cooling water back into the Missouri River.

6.2.4 FLOW TRAVEL TIMES

For purposes of scheduling releases, approximate open water travel times from Gavins Point Dam are 1.5 days to Sioux City; 3 days to Omaha; 3.5 days to Nebraska City; 5.5 days to Kansas City; and 10 days to the mouth of the Missouri River near St. Louis.

6.3 HISTORIC FLOW CONDITIONS (1967 TO 2010)

Historic flow conditions for the period 1967 through 2010 were determined from Corps and USGS gaging sites along the Missouri River from Gavins Point Dam to Rulo, NE. The gaging sites include: Gavins Point Dam; Omaha (USGS 06610000); Nebraska City (USGS 06807000); and Rulo (06813500). Box plots showing the distribution of the mean daily flows measured over the 44-year period are shown in Figure 6-1.

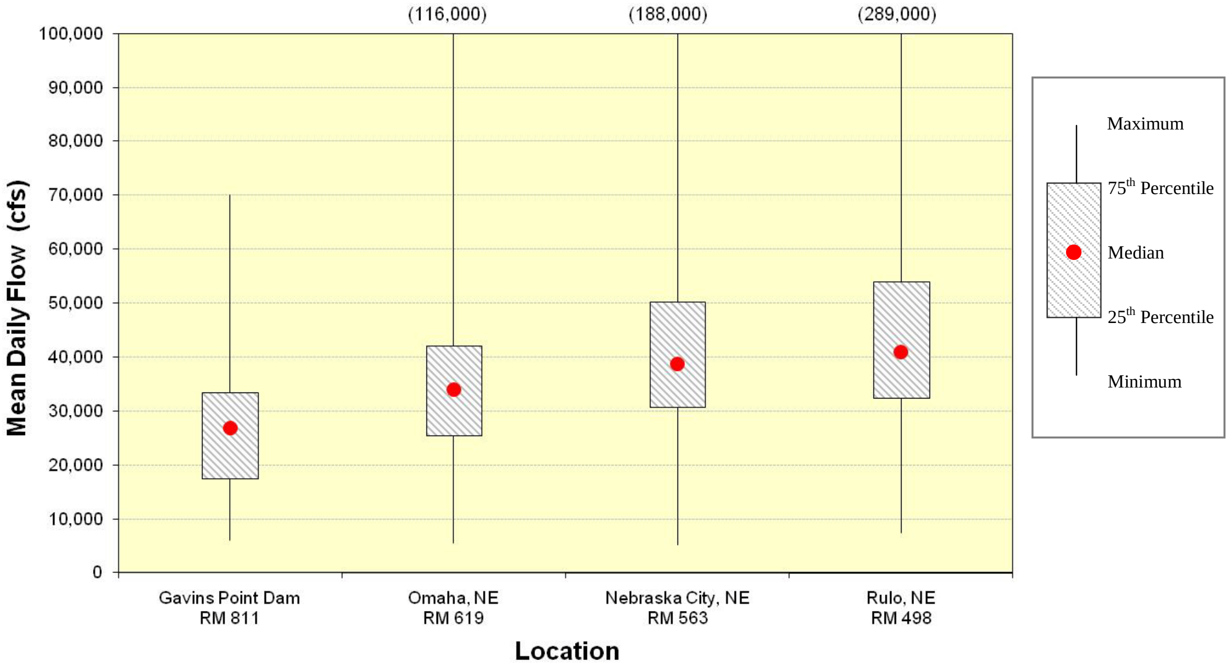


Figure 6-1. Distribution of mean daily flows recorded at gaging sites on the Missouri River at Gavins Point Dam, Omaha, NE, Nebraska City, NE, and Rulo, NE during the 44-year period of 1967 through 2010.

6.4 NATIONAL RECREATION RIVER DESIGNATION PURSUANT TO THE FEDERAL WILD AND SCENIC RIVERS ACT

The 59-mile "natural-channel" reach from Gavins Point Dam to Ponca State Park, NE has been designated as a National Recreational River under the Federal Wild and Scenic Rivers Act (WSRA). The National Park Service (NPS) manages the reach under the WSRA. The justification that supported that this reach of the Missouri River be protected as a recreational river identified its outstanding remarkable recreational, fish and wildlife, aesthetic, historical, and cultural values. Under the WSRA, the U.S. Department of Interior (i.e., NPS) is mandated to administer this reach in a manner that will protect and enhance these values for the benefit and enjoyment of present and future generations.

6.5 STATE DESIGNATIONS AND LISTINGS PURSUANT TO THE FEDERAL CLEAN WATER ACT

Pursuant to the Federal Clean Water Act (CWA), the States of South Dakota, Nebraska, Iowa, and Missouri have designated water quality-dependent beneficial uses, in their State water quality standards, for appropriate reaches of the Missouri River downstream of Gavins Point Dam to Rulo, NE. South Dakota has designated the following uses for all of the Missouri River within the state downstream of Gavins Point Dam: primary contact recreation, warmwater fishery, drinking water supply, and industrial water supply. Nebraska has designated the following uses to the entire length of the Missouri River in Nebraska: primary contact recreation, warmwater aquatic life, agricultural water supply, and aesthetics. It has designated the use of drinking water supply to the river downstream of the confluence of the Niobrara River, and industrial water supply to the river downstream of the confluence of the Big Sioux River. Nebraska has also designated the reach between Gavins Point Dam and Ponca State Park as Outstanding State Resource Waters for "Tier 3" protection under the State's water quality standards' antidegradation policy. Iowa has designated the following uses to all of the Missouri River in the state: primary contact recreation, warmwater fishery, and high quality state resource water. It has also

designated the use of drinking water supply to the river in the area of Council Bluffs, IA. Missouri has designated the following uses to the river: primary contact recreation, warmwater fishery, drinking water supply, agricultural water supply, and industrial water supply. The States of Nebraska, Iowa, and Missouri have listed the Missouri River on their State's Section 303(d) list of impaired waters. The pollutant/stressors identified are pathogens, Dieldrin, PCBs, and arsenic. The source of Dieldrin and PCBs is residual contamination, as both substances have been banned since the 1980's. The identified sources for the pathogens are municipal point sources, agriculture, and urban runoff.

6.6 EXISTING WATER QUALITY CONDITIONS ALONG THE LOWER MISSOURI RIVER FROM GAVINS POINT DAM TO RULO, NEBRASKA

The Omaha District, in cooperation with the Nebraska Department of Environmental Quality (NDEQ), conducted fixed-station water quality monitoring at seven sites along the Missouri River from Gavins Point Dam to Rulo, NE during the 5-year period of 2006 through 2010. The location of the seven sites were Gavins Point Dam tailwaters (site GPTRRTW1); near Maskell, NE (site MORRR0774); near Ponca, NE (site MORRR0753); at Decatur, NE (site MORRR0691); at Omaha, NE (site MORRR0619); at Nebraska City, NE (site MORRR0563); and at Rulo, NE (site MORRR0498) (Figure 6-2).

6.6.1 GAVINS POINT DAM TAILWATERS (SITE GPTRRTW1) – RM810

Water quality samples at site GPTRRTW1 were collected monthly from October through March and biweekly from April through September during the 2 years 2006 and 2007. During the 3-year period 2008 through 2010 water quality samples were collected monthly year-round. During the 4-year period 2006 through 2009, a near-surface grab sample was collected from the bank in an area of faster current. In 2010 sampling during the period March through October was conducted from a boat in the thalweg of the river; otherwise, samples were collected from the bank in an area of faster current. When sampling was done from a boat depth-discrete samples were collected and depth-profile measurements were taken from the water surface to river bottom.

6.6.1.1 Near-Surface Water Quality Conditions

6.6.1.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 422 summarizes the near-surface water quality conditions that were monitored at site GPTRRTW1 during the 5-year period 2006 through 2010. A review of these results indicated no major water quality concerns.

6.6.1.1.2 Nutrient Flux Conditions

Nutrient flux rates for the Missouri River at the Gavins Point Dam tailwaters were calculated for the 5-year period 2006 through 2010. The calculated flux rates were based on near-surface water quality samples collected at site GPTRRTW1 and the instantaneous flow conditions at the time of sample collection (Table 6-1). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) could seemingly be higher nearer the river bottom, near-surface grab samples likely under estimate the "true" water-column composite concentration for these constituents. Thus, the given flux rates for total phosphorus and total organic carbon should be considered minimum estimates with the actual flux rates being potentially higher.

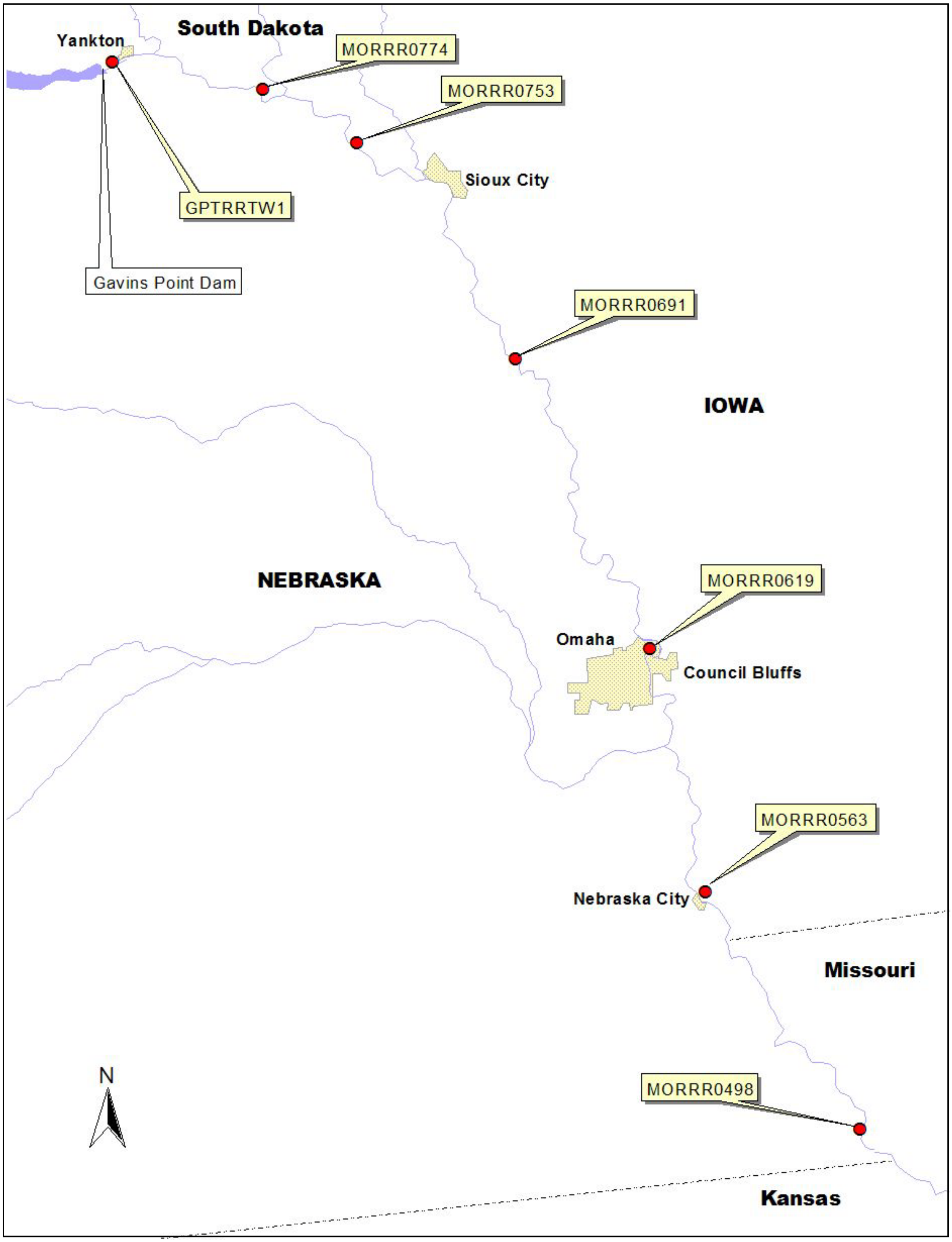


Figure 6-2. Locations of water quality monitoring sites along the Missouri River from Gavins Point Dam to Rulo, NE.

Table 6-1. Summary of near-surface nutrient flux rates (kg/sec) calculated for the Missouri River at the Gavins Point tailwaters (i.e., site GTPRRTW1) over the 5-year period 2006 through 2010.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	73	73	73	72	73	71
Mean	18,814	0.0359	0.3006	0.0695	0.0249	1.9566
Median	16,981	0.0190	0.2327	0.0468	0.0227	1.5942
Minimum	8,000	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	46,937	0.2527	1.3260	0.3859	0.0906	6.1137

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

6.6.1.2 Vertical Water Quality Variation

Depth discrete water quality monitoring of the Missouri River at site GPTRRTW1 was initiated in 2010. Depth-profiles for water temperature, dissolved oxygen, pH, conductivity, ORP, turbidity, and chlorophyll *a* were measured in ½-meter increments while drifting in a boat along the river thalweg. Near-surface, mid-depth, and near-bottom grab samples were also collected from the thalweg of the river. The near-surface sample was collected by dipping a plastic churn bucket just below the water surface. The mid-depth and near-bottom samples were collected by triggering a finned-Van Dorn sampler at the appropriate depth while the boat was drifting in the current.

6.6.1.2.1 Depth-Profile Plots

Depth-profile plots were constructed for water temperature, dissolved oxygen, pH, conductivity, turbidity, and chlorophyll *a* (Plate 423). The depth-profile plots indicate minimal variation in the six parameters with depth, with chlorophyll *a* showing the most variation. The plots do indicate appreciable differences for selected parameters between monitoring dates.

6.6.1.2.2 Comparison of Near-Surface, Mid-Depth and Near-Bottom Water Quality Conditions

The near-surface, mid-depth, and near-bottom concentrations of the particulate-associated constituents total phosphorus, total Kjeldahl nitrogen, total suspended solids, total suspended sediment, and total organic carbon measured at site GPTRRTW1 were plotted against the flow of the Missouri River at the time of sampling (Plate 424). The measured concentrations of the particulate-associated constituents exhibited little observable correlation to depth, and seemingly only a slight increase with increasing flow. This may be attributed to the site location (i.e., dam tailwaters) and the impacts of the dam and upstream reservoir on the discharged water.

Paired near-surface, mid-depth, and near-bottom water quality samples collected at site GPTRRTW1 during 2010 were compared. Seven paired samples (April, May, June, July, August, September, and October) were collected during 2010. Box plots were constructed to display the distribution of the paired near-surface, mid-depth, and near-bottom measurements for selected non-particulate-associated (i.e., water temperature and specific conductance) and particulate-associated (i.e., total suspended solids, total suspended sediment, turbidity, total Kjeldahl nitrogen, total phosphorus, and total organic carbon) constituents (Plate 425). Anecdotally, the box plots indicate little observable depth variation in the non-particulate-associated constituents. The box plots of the particulate-associated

constituents exhibited more variation. A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different (α = 0.05). The sampled near-surface and near-bottom conditions were not found to be significantly different for any parameter.

6.6.2 MISSOURI RIVER NEAR MASKELL, NEBRASKA (SITE MORRR0774) – RM774

Water quality samples at site MORRR0774 were collected monthly from October through March and biweekly from April through September during the 2 years 2006 and 2007. During the 3-year period 2008 through 2010 water quality samples were collected monthly year-round. During the 5-year period 2006 through 2010, a near-surface grab sample was collected from the bank in an area of faster current.

6.6.2.1 Near-Surface Water Quality Conditions

6.6.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 426 summarizes the near-surface water quality conditions that were monitored at site MORRR0744 during the 5-year period 2006 through 2010. A review of these results indicated no major water quality concerns.

6.6.2.1.2 Nutrient Flux Conditions

Nutrient flux rates for the Missouri River near Maskell, Nebraska at RM774 were calculated for the 5-year period 2006 through 2010. The calculated flux rates were based on near-surface water quality samples collected at site MORRR0774 and the instantaneous flow conditions at the time of sample collection (Table 6-2). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) could seemingly be higher nearer the river bottom, near-surface grab samples likely under estimate the "true" water-column composite concentration for these constituents. Thus, the given flux rates for total phosphorus and total organic carbon should be considered minimum estimates with the actual flux rates being potentially higher.

Table 6-2. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Maskell, Nebraska at RM774 over the 5-year period 2006 through 2010.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	55	55	55	55	55	53
Mean	23,204	0.0426	0.3939	0.1104	0.0546	2.5534
Median	23,312	0.0198	0.3563	0.0806	0.0428	2.2475
Minimum	9,337	n.d.	n.d.	n.d.	n.d.	0.5718
Maximum	45,977	0.2465	0.9048	0.5166	0.2015	8.2523

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

6.6.3 MISSOURI RIVER NEAR PONCA, NEBRASKA (SITE MORRR0753) – RM753

Water quality samples at site MORRR0753 were collected monthly from October through March and biweekly from April through September during the 2 years 2006 and 2007. During the 3-year period 2008 through 2010 water quality samples were collected monthly year-round. During the 4-year period 2006 through 2009, a near-surface grab sample was collected from the bank in an area of faster current. In 2010 sampling during the period March through October was conducted from a boat in the thalweg of the river; otherwise, samples were collected from the bank in an area of faster current. When sampling was done from a boat depth-discrete samples were collected and depth-profile measurements were taken from the water surface to river bottom.

6.6.3.1 <u>Near-Surface Water Quality Conditions</u>

6.6.3.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 427 summarizes the near-surface water quality conditions that were monitored at site MORRR0753 during the 5-year period 2006 through 2010. A review of these results indicated no major water quality concerns.

6.6.3.1.2 Nutrient Flux Conditions

Nutrient flux rates for the Missouri River near Ponca, Nebraska at RM753 were calculated for the 5-year period 2006 through 2010. The calculated flux rates were based on near-surface water quality samples collected at site MORRR0753 and the instantaneous flow conditions at the time of sample collection (Table 6-3). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) could seemingly be higher nearer the river bottom, near-surface grab samples likely under estimate the "true" water-column composite concentration for these constituents. Thus, the given flux rates for total phosphorus and total organic carbon should be considered minimum estimates with the actual flux rates being potentially higher.

Table 6-3. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Ponca, Nebraska at RM753 over the 5-year period 2006 through 2010.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	57	57	57	57	57	55
Mean	23,556	0.0460	0.4898	0.1006	0.0804	2.9332
Median	23,369	0.0215	0.3996	0.0445	0.0555	2.5392
Minimum	9,452	n.d.	0.0970	n.d.	n.d.	0.7571
Maximum	54,168	0.2688	1.5858	0.6820	0.2718	10.2766

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

6.6.3.2 Vertical Water Quality Variation

Depth discrete water quality monitoring of the Missouri River at site MORRR0753 was initiated in 2010. Depth-profiles for water temperature, dissolved oxygen, pH, conductivity, ORP, turbidity, and chlorophyll *a* were measured in ½-meter increments while drifting in a boat along the river thalweg. Near-surface, mid-depth, and near-bottom grab samples were also collected from the thalweg of the river. The near-surface sample was collected by dipping a plastic churn bucket just below the water surface. The mid-depth and near-bottom samples were collected by triggering a finned-Van Dorn sampler at the appropriate depth while the boat was drifting in the current.

6.6.3.2.1 Depth-Profile Plots

Depth-profile plots were constructed for water temperature, dissolved oxygen, pH, conductivity, turbidity, and chlorophyll *a* (Plate 428). The depth-profile plots indicate minimal variation in the six parameters with depth. The plots do indicate appreciable differences for selected parameters between monitoring dates.

6.6.3.2.2 Comparison of Near-Surface, Mid-Depth and Near-Bottom Water Quality Conditions

The near-surface, mid-depth, and near-bottom concentrations of the particulate-associated constituents total phosphorus, total Kjeldahl nitrogen, total suspended solids, total suspended sediment, and total organic carbon measured at site MORRR0753 were plotted against the flow of the Missouri River at the time of sampling (Plate 429). The measured concentrations of the particulate-associated constituents exhibited some observable correlation to depth and seemingly little correlation to flow.

Paired near-surface, mid-depth, and near-bottom water quality samples collected at site MORRR0753 during 2010 were compared. Seven paired samples (April, May, June, July, August, September, and October) were collected during 2010. Box plots were constructed to display the distribution of the paired near-surface, mid-depth, and near-bottom measurements for selected non-particulate-associated (i.e., water temperature and specific conductance) and particulate-associated (i.e., total suspended solids, total suspended sediment, turbidity, total Kjeldahl nitrogen, total phosphorus, and total organic carbon) constituents (Plate 430). Anecdotally, the box plots indicate little observable depth variation in the non-particulate-associated constituents. The box plots of the particulate-associated constituents exhibited more variation, with total suspended solids, total suspended sediment, and total Kjeldahl nitrogen seemingly higher near the bottom. A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different (α = 0.05). The sampled near-surface and near-bottom conditions were not found to be significantly different for any parameter. However, total suspended sediment was nearly significant different (p = 0.08) with total suspended solids (p = 0.18) and total Kjeldahl nitrogen (p = 0.12) showing less significance.

6.6.4 MISSOURI RIVER AT DECATUR, NEBRASKA (SITE MORRR0691) – RM691

Water quality samples at site MORRR0691 were collected monthly from October through March and biweekly from April through September during the 2 years 2006 and 2007. During the 3-year period 2008 through 2010 water quality samples were collected monthly year-round. During the 4-year period 2006 through 2009, a near-surface grab sample was collected from the bank in an area of faster current. In 2010 sampling during the period March through October was conducted from a boat in the thalweg of the river; otherwise, samples were collected from the bank in an area of faster current. When sampling was done from a boat depth-discrete samples were collected and depth-profile measurements were taken from the water surface to river bottom.

6.6.4.1 <u>Near-Surface Water Quality Conditions</u>

6.6.4.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 431 summarizes the near-surface water quality conditions that were monitored at site MORRR0691 during the 5-year period 2006 through 2010. A review of these results indicated no major water quality concerns.

6.6.4.1.2 Nutrient Flux Conditions

Nutrient flux rates for the Missouri River at Decatur, Nebraska at RM691 were calculated for the 5-year period 2006 through 2010. The calculated flux rates were based on near-surface water quality samples collected at site MORRR0691 and the instantaneous flow conditions at the time of sample collection (Table 6-4). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) could seemingly be higher nearer the river bottom, near-surface grab samples likely under estimate the "true" water-column composite concentration for these constituents. Thus, the given flux rates for total phosphorus and total organic carbon should be considered minimum estimates with the actual flux rates being potentially higher.

Table 6-4. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Decatur, Nebraska at RM691 over the 5-year period 2006 through 2010.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	70	70	70	69	70	68
Mean	27,414	0.0746	0.8071	0.9644	0.1690	3.6662
Median	26,150	0.0427	0.5770	0.5788	0.0958	2.9753
Minimum	12,300	n.d.	n.d.	n.d.	n.d.	0.7140
Maximum	76,235	0.4969	4.6106	5.8897	1.0123	14.6790

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

6.6.4.2 <u>Vertical Water Quality Variation</u>

Depth discrete water quality monitoring of the Missouri River at site MORRR0691 was initiated in 2010. Depth-profiles for water temperature, dissolved oxygen, pH, conductivity, ORP, turbidity, and chlorophyll *a* were measured in ½-meter increments while drifting in a boat along the river thalweg. Near-surface, mid-depth, and near-bottom grab samples were also collected from the thalweg of the river. The near-surface sample was collected by dipping a plastic churn bucket just below the water surface. The mid-depth and near-bottom samples were collected by triggering a finned-Van Dorn sampler at the appropriate depth while the boat was drifting in the current.

6.6.4.2.1 Depth-Profile Plots

Depth-profile plots were constructed for water temperature, dissolved oxygen, pH, conductivity, turbidity, and chlorophyll *a* (Plate 432). The depth-profile plots indicate minimal variation in the six parameters with depth. The plots do indicate appreciable differences for selected parameters between monitoring dates.

6.6.4.2.2 Comparison of Near-Surface, Mid-Depth and Near-Bottom Water Quality Conditions

The near-surface, mid-depth, and near-bottom concentrations of the particulate-associated constituents total phosphorus, total Kjeldahl nitrogen, total suspended sediment, total suspended solids, and total organic carbon measured at site MORRR0691 were plotted against the flow of the Missouri River at the time of sampling (Plate 433). The measured concentrations of the particulate-associated constituents exhibited some observable correlation to depth and seemingly little correlation to flow. High levels of suspended sediment occurred in the near-bottom samples on two occasions and are likely due to the capture of suspended bedload.

Paired near-surface, mid-depth, and near-bottom water quality samples collected at site MORRR0691 during 2010 were compared. Seven paired samples (April, May, June, July, August, September, and October) were collected during 2010. Box plots were constructed to display the distribution of the paired near-surface, mid-depth, and near-bottom measurements for selected non-particulate-associated (i.e., water temperature and specific conductance) and particulate-associated (i.e., total suspended solids, total suspended sediment, turbidity, total Kjeldahl nitrogen, total phosphorus, and total organic carbon) constituents (Plate 434). Anecdotally, the box plots indicate little observable depth variation in the non-particulate-associated constituents. The box plots of the particulate-associated constituents exhibited more variation, with total suspended sediment and total Kjeldahl nitrogen seemingly higher near the bottom. A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were not found to be significantly different for any parameter. However, total Kjeldahl nitrogen was nearly significant different ($p = 0.06$) with total suspended sediment ($p = 0.16$) and showing less significance.

6.6.5 MISSOURI RIVER AT OMAHA, NEBRASKA (SITE MORRR0619) – RM619

Water quality samples at site MORRR0619 were collected monthly from October through March and biweekly from April through September during the 2 years 2006 and 2007. During the 3-year period 2008 through 2010 water quality samples were collected monthly year-round. During the 4-year period 2006 through 2009, a near-surface grab sample was collected from the bank in an area of faster current. In 2010 sampling during the period March through October was conducted from a boat in the thalweg of the river; otherwise, samples were collected from the bank in an area of faster current. When sampling was done from a boat depth-discrete samples were collected and depth-profile measurements were taken from the water surface to river bottom.

6.6.5.1 Near-Surface Water Quality Conditions

6.6.5.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 435 summarizes the near-surface water quality conditions that were monitored at site MORRR0619 during the 5-year period 2006 through 2010. A review of these results indicated no major water quality concerns.

6.6.5.1.2 Nutrient Flux Conditions

Nutrient flux rates for the Missouri River at Omaha, Nebraska at RM619 were calculated for the 5-year period 2006 through 2010. The calculated flux rates were based on near-surface water quality samples collected at site MORRR0619 and the instantaneous flow conditions at the time of sample collection (Table 6-5). It must be recognized that the concentrations of particulate-associated constituents

can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) could seemingly be higher nearer the river bottom, near-surface grab samples likely under estimate the "true" water-column composite concentration for these constituents. Thus, the given flux rates for total phosphorus and total organic carbon should be considered minimum estimates with the actual flux rates being potentially higher.

Table 6-5. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Omaha, Nebraska at RM619 over the 5-year period 2006 through 2010.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	72	72	72	71	72	70
Mean	31,926	0.1096	1.2433	1.8167	0.3635	4.5663
Median	29,650	0.0447	0.7045	1.1508	0.1378	3.2470
Minimum	11,600	n.d.	n.d.	n.d.	0.0228	1.0385
Maximum	96,611	1.1869	8.0279	8.4164	3.3150	19.4224

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

6.6.5.2 Vertical Water Quality Variation

Depth discrete water quality monitoring of the Missouri River at site MORRR0619 was initiated in 2010. Depth-profiles for water temperature, dissolved oxygen, pH, conductivity, ORP, turbidity, and chlorophyll *a* were measured in ½-meter increments while drifting in a boat along the river thalweg. Near-surface, mid-depth, and near-bottom grab samples were also collected from the thalweg of the river. The near-surface sample was collected by dipping a plastic churn bucket just below the water surface. The mid-depth and near-bottom samples were collected by triggering a finned-Van Dorn sampler at the appropriate depth while the boat was drifting in the current.

6.6.5.2.1 Depth-Profile Plots

Depth-profile plots were constructed for water temperature, dissolved oxygen, pH, conductivity, turbidity, and chlorophyll *a* (Plate 436). The depth-profile plots indicate minimal variation in the six parameters with depth. The plots do indicate appreciable differences for selected parameters between monitoring dates.

6.6.5.2.2 Comparison of Near-Surface, Mid-Depth and Near-Bottom Water Quality Conditions

The near-surface, mid-depth, and near-bottom concentrations of the particulate-associated constituents total phosphorus, total Kjeldahl nitrogen, total suspended sediment, total suspended solids, and total organic carbon measured at site MORRR0619 were plotted against the flow of the Missouri River at the time of sampling (Plate 437). The measured concentrations of the particulate-associated constituents exhibited some observable correlation to depth and flow.

Paired near-surface, mid-depth, and near-bottom water quality samples collected at site MORRR0619 during 2010 were compared. Five paired samples (April, May, June, September, and October) were collected during 2010. Box plots were constructed to display the distribution of the paired

near-surface, mid-depth, and near-bottom measurements for selected non-particulate-associated (i.e., water temperature and specific conductance) and particulate-associated (i.e., total suspended solids, total suspended sediment, turbidity, total Kjeldahl nitrogen, total phosphorus, and total organic carbon) constituents (Plate 438). Anecdotally, the box plots indicate little observable depth variation in the non-particulate-associated constituents. The box plots of the particulate-associated constituents exhibited more variation, with some parameters seemingly higher near the bottom. A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were found to be significantly different for total suspended sediment, total phosphorus, and total organic carbon; and turbidity was nearly significant different ($p = 0.06$).

6.6.6 MISSOURI RIVER AT NEBRASKA CITY, NEBRASKA (SITE MORRR0563) – RM563

Water quality samples at site MORRR0563 were collected monthly from October through March and biweekly from April through September during the 2 years 2006 and 2007. During the 3-year period 2008 through 2010 water quality samples were collected monthly year-round. During the 4-year period 2006 through 2009, a near-surface grab sample was collected from the bank in an area of faster current. In 2010 sampling during the period March through October was conducted from a boat in the thalweg of the river; otherwise, samples were collected from the bank in an area of faster current. When sampling was done from a boat depth-discrete samples were collected and depth-profile measurements were taken from the water surface to river bottom.

6.6.6.1 <u>Near-Surface Water Quality Conditions</u>

6.6.6.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 439 summarizes the near-surface water quality conditions that were monitored at site MORRR0563 during the 5-year period 2006 through 2010. A review of these results indicated no major water quality concerns.

6.6.6.1.2 Nutrient Flux Conditions

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Nutrient flux rates for the Missouri River at Nebraska City, Nebraska at RM563 were calculated for the 5-year period 2006 through 2010. The calculated flux rates were based on near-surface water quality samples collected at site MORRR0563 and the instantaneous flow conditions at the time of sample collection (Table 6-6). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) could seemingly be higher nearer the river bottom, near-surface grab samples likely under estimate the “true” water-column composite concentration for these constituents. Thus, the given flux rates for total phosphorus and total organic carbon should be considered minimum estimates with the actual flux rates being potentially higher.

Table 6-6. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Nebraska City, Nebraska at RM563 over the 5-year period 2006 through 2010.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	71	714	71	70	71	69
Mean	39,050	0.1642	1.8903	2.1755	0.5886	5.9790
Median	35,300	0.1045	1.0534	1.5497	0.2484	3.8736
Minimum	16,000	n.d.	0.3263	0.0407	0.0550	1.2460
Maximum	117,000	1.4731	12.7881	10.9328	5.6321	38.6692

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

6.6.6.2 Vertical Water Quality Variation

Depth discrete water quality monitoring of the Missouri River at site MORRR0563 was initiated in 2010. Depth-profiles for water temperature, dissolved oxygen, pH, conductivity, ORP, turbidity, and chlorophyll *a* were measured in ½-meter increments while drifting in a boat along the river thalweg. Near-surface, mid-depth, and near-bottom grab samples were also collected from the thalweg of the river. The near-surface sample was collected by dipping a plastic churn bucket just below the water surface. The mid-depth and near-bottom samples were collected by triggering a finned-Van Dorn sampler at the appropriate depth while the boat was drifting in the current.

6.6.6.2.1 Depth-Profile Plots

Depth-profile plots were constructed for water temperature, dissolved oxygen, pH, conductivity, turbidity, and chlorophyll *a* (Plate 440). The depth-profile plots indicate minimal variation in the six parameters with depth. The plots do indicate appreciable differences for selected parameters between monitoring dates.

6.6.6.2.2 Comparison of Near-Surface, Mid-Depth and Near-Bottom Water Quality Conditions

The near-surface, mid-depth, and near-bottom concentrations of the particulate-associated constituents total phosphorus, total Kjeldahl nitrogen, total suspended sediment, total suspended solids, and total organic carbon measured at site MORRR0563 were plotted against the flow of the Missouri River at the time of sampling (Plate 441). Near-bottom concentrations of the particulate-associated constituents tended to be higher than the near-surface levels during most instances.

Paired near-surface, mid-depth, and near-bottom water quality samples collected at site MORRR0563 during 2010 were compared. Five paired samples (April, May, June, September, and October) were collected during 2010. Box plots were constructed to display the distribution of the paired near-surface, mid-depth, and near-bottom measurements for selected non-particulate-associated (i.e., water temperature and specific conductance) and particulate-associated (i.e., total suspended solids, total suspended sediment, turbidity, total Kjeldahl nitrogen, total phosphorus, and total organic carbon) constituents (Plate 442). Anecdotally, the box plots indicate little observable depth variation in the non-particulate-associated constituents. The box plots of the particulate-associated constituents exhibited more variation, with some parameters seemingly higher near the bottom. A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were

significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were found to be significantly different for turbidity; and total phosphorus (p = 0.07) and total suspended sediment (p = 0.11) were nearly significantly different.

6.6.7 MISSOURI RIVER AT RULO, NEBRASKA (SITE MORRR0498) – RM498

Water quality samples at site MORRR0498 were collected monthly from October through March and biweekly from April through September during the 2 years 2006 and 2007. During the 3-year period 2008 through 2010 water quality samples were collected monthly year-round. During the 4-year period 2006 through 2009, a near-surface grab sample was collected from the bank in an area of faster current. In 2010 sampling during the period March through October was conducted from a boat in the thalweg of the river; otherwise, samples were collected from the bank in an area of faster current. When sampling was done from a boat depth-discrete samples were collected and depth-profile measurements were taken from the water surface to river bottom.

6.6.7.1 Near-Surface Water Quality Conditions

6.6.7.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 443 summarizes the near-surface water quality conditions that were monitored at site MORRR0498 during the 5-year period 2006 through 2010. A review of these results indicated no major water quality concerns.

6.6.7.1.2 Nutrient Flux Conditions

Nutrient flux rates for the Missouri River at Rulo, Nebraska at RM498 were calculated for the 5-year period 2006 through 2010. The calculated flux rates were based on near-surface water quality samples collected at site MORRR0498 and the instantaneous flow conditions at the time of sample collection (Table 6-7). It must be recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Since the instantaneous concentration of particulate-associated constituents (i.e., total phosphorus and total organic carbon) could seemingly be higher nearer the river bottom, near-surface grab samples likely under estimate the “true” water-column composite concentration for these constituents. Thus, the given flux rates for total phosphorus and total organic carbon should be considered minimum estimates with the actual flux rates being potentially higher.

Table 6-7. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Rulo, Nebraska at RM498 over the 5-year period 2006 through 2010.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	71	71	71	70	71	69
Mean	42,458	0.1445	1.7968	2.6022	0.6277	5.9557
Median	35,500	0.0690	1.0403	1.7107	0.2881	3.8736
Minimum	17,500	n.d.	0.3270	0.0295	0.0732	0.9682
Maximum	131,000	1.4039	10.0321	12.2410	5.2883	32.4655

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

6.6.7.2 <u>Vertical Water Quality Variation</u>

Depth discrete water quality monitoring of the Missouri River at site MORRR0498 was initiated in 2010. Depth-profiles for water temperature, dissolved oxygen, pH, conductivity, ORP, turbidity, and chlorophyll *a* were measured in ½-meter increments while drifting in a boat along the river thalweg. Near-surface, mid-depth, and near-bottom grab samples were also collected from the thalweg of the river. The near-surface sample was collected by dipping a plastic churn bucket just below the water surface. The mid-depth and near-bottom samples were collected by triggering a finned-Van Dorn sampler at the appropriate depth while the boat was drifting in the current.

6.6.7.2.1 Depth-Profile Plots

Depth-profile plots were constructed for water temperature, dissolved oxygen, pH, conductivity, turbidity, and chlorophyll *a* (Plate 444). The depth-profile plots indicate minimal variation in the six parameters with depth. The plots do indicate appreciable differences for selected parameters between monitoring dates.

6.6.7.2.2 Comparison of Near-Surface, Mid-Depth and Near-Bottom Water Quality Conditions

The near-surface, mid-depth, and near-bottom concentrations of the particulate-associated constituents total phosphorus, total Kjeldahl nitrogen, total suspended sediment, total suspended solids, and total organic carbon measured at site GPTRRTW1 were plotted against the flow of the Missouri River at the time of sampling (Plate 445). Near-bottom concentrations of the particulate-associated constituents were generally higher than the near-surface levels.

Paired near-surface, mid-depth, and near-bottom water quality samples collected at site MORRR0498 during 2010 were compared. Six paired samples (April, May, June, August, September, and October) were collected during 2010. Box plots were constructed to display the distribution of the paired near-surface, mid-depth, and near-bottom measurements for selected non-particulate-associated (i.e., water temperature and specific conductance) and particulate-associated (i.e., total suspended solids, total suspended sediment, turbidity, total Kjeldahl nitrogen, total phosphorus, and total organic carbon) constituents (Plate 445). Anecdotally, the box plots indicate little observable depth variation in the non-particulate-associated constituents. The box plots of the particulate-associated constituents exhibited more variation, with some parameters seemingly higher near the bottom. A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were found to be significantly different for turbidity, total phosphorus, and total organic carbon.

6.6.8 LONGITUDINAL VARIATION IN WATER QUALITY ALONG THE LOWER MISSOURI RIVER

The levels of selected parameters measured in near-surface samples collected at each of the seven monitoring sites along the lower Missouri River over the 5-year period 2006 through 2010 were depicted as box plots. The parameters plotted include dissolved oxygen, pH, specific conductance, chloride, turbidity, total suspended solids, chemical oxygen demand, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, total nitrate-nitrite nitrogen, total phosphorus, and atrazine (Plate 447). For comparison purposes, box plots for the individual parameters measured at each of the seven sites are arranged relative to their respective location in an upstream to downstream order (i.e., GPTRRTW1 = RM811, MORRR0774 = RM774, MORRR0753 = RM753, MORR0691 = RM691, MORR0619 = RM619, MORR0563 = RM563, and MORR0498 = RM498). Four longitudinal trends were categorized based on the constructed longitudinal box plots: 1) parameter exhibits no observable longitudinal trend, 2)

parameter slightly decreases in a downstream direction, 3) parameter slightly increases in a downstream direction, and 4) parameter greatly increases in a downstream direction. Parameters that exhibited no observable longitudinal trend included pH, specific conductance, total organic carbon, and total ammonia. Dissolved oxygen is the only parameter that slightly decreased in a downstream direction. Parameters that slightly increased in a downstream direction included chemical oxygen demand, total Kjeldahl nitrogen, and atrazine. Parameters that greatly increased in a downstream direction included chloride, turbidity, total suspended solids, nitrate-nitrite nitrogen, and total phosphorus.

6.6.9 WATER TEMPERATURES MONITORED ALONG THE LOWER MISSOURI RIVER IN 2010

Mean daily water temperatures were calculated from USGS and Corps data recorded in 2010 at monitoring locations along the lower Missouri River. Plate 448 plots 2010 mean daily water temperatures for the Missouri River at Gavins Point Dam; Sioux City, IA; and St. Joseph, MO. In the spring and summer, mean daily water temperatures in the Missouri River are generally about 3 to 4° C warmer at St. Joseph, MO as compared to the discharges from Gavins Point Dam.

6.7 ESTIMATED CURRENT NUTRIENT CONCENTRATIONS AND MEAN DAILY LOADS ALONG THE MISSOURI RIVER IN THE OMAHA DISTRICT

Nutrient (i.e., nitrate-nitrite nitrogen, total nitrogen, and total phosphorus) concentrations and mean daily loads for the Missouri River at selected locations in the Omaha District were compiled from monitoring conducted during the 5-year period of 2006 through 2010. The monitored locations along the Missouri River included the following 16 sites (listed in an upstream to downstream order with the river mile given): 1) near Landusky, MT [RM 1921]; 2) at Fort Peck Dam [RM 1771]; 3) Near Williston, ND [RM 1553]; 4) at Garrison Dam [RM 1389]; 5) at Bismarck, ND [RM 1315]; 6) at Oahe Dam [RM 1072]; 7) at Big Bend Dam [RM 986]; 8) at Fort Randall Dam [RM 879]; 9) near Verdel, NE [RM 851]; 10) at Gavins Point Dam [RM 811]; 11) near Maskell, NE [RM 774]; 12) near Ponca, NE [RM 753]; 13) at Decatur, NE [RM 691]; 14) at Omaha, NE [RM 619]; 15) at Nebraska City, NE [RM 563]; and 16) at Rulo, NE [RM 498]. The samples collected at the mainstem dams were collected at the respective powerplants and are representative of the water discharged from the dams. The other samples collected along the Missouri River were grab samples representative of near-surface conditions.

6.7.1 EXISTING NUTRIENT CONCENTRATIONS MEASURED ALONG THE MISSOURI RIVER

Box plots were constructed from the total nitrate-nitrite nitrogen, total nitrogen, and total phosphorus concentrations measured along the Missouri River at the 16 locations during the 5-year period 2006 through 2010 (Figure 6-3). As seen in Figure 6-3, there is a significant increase in nitrate-nitrite nitrogen levels downstream of Gavins Point Dam; especially downstream of Ponca, NE (RM753). Large cities (i.e., Sioux City, IA and Omaha, NE) and tributary streams draining areas of intensive agriculture are located downstream of Gavins Point Dam. An increase in total phosphorus levels is also seen downstream of Gavins Point Dam (Figure 6-3). Higher levels of total phosphorus were also measured in the Missouri River near Landusky, MT (RM1921 – inflow to Fort Peck Lake) and Williston, ND (RM1553 – inflow to Lake Sakakawea). It is noted that the Yellowstone River enters the Missouri River downstream of Fort Peck Dam and upstream from Williston, ND.

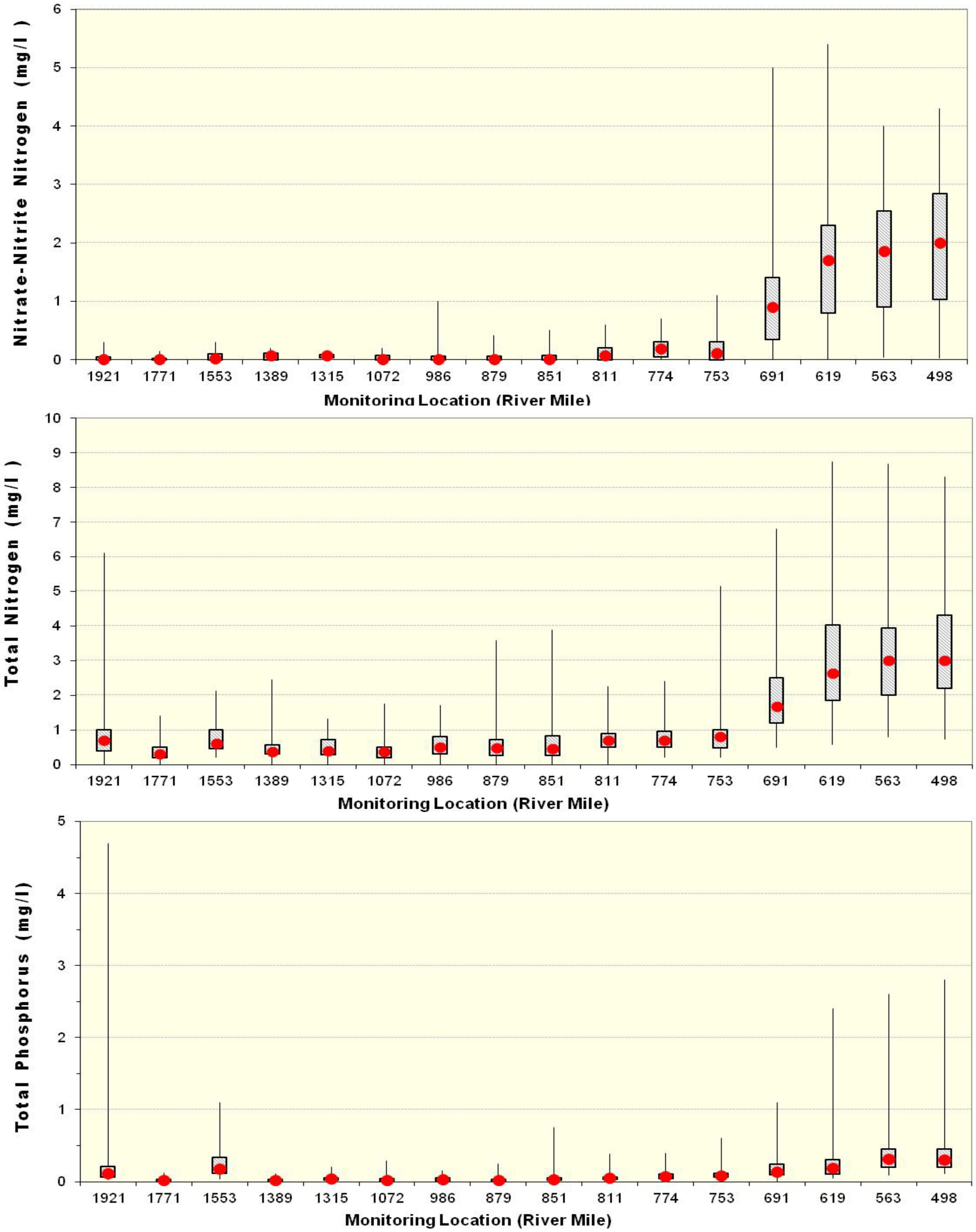

Figure 6-3. Distribution of measured concentrations of nitrate-nitrite nitrogen, total nitrogen, and total phosphorus at 16 locations along the Missouri River from Landusky, MT (RM1921) to Rulo, NE (RM498) during the 5-year period 2006 through 2010. (Box plots represent minimum, 25th percentile, 75th percentile, and maximum. Red dot is the median value).

6.7.2 EXISTING NUTRIENT LOADINGS ESTIMATED ALONG THE MISSOURI RIVER

Loadings for total nitrate-nitrite nitrogen, total nitrogen, and total phosphorus were estimated for the Missouri River at the 16 locations based on the powerplant and near-surface sampling data collected over the 5-year period 2006 through 2010. Daily loadings were calculated from the instantaneous flux rates determined for the sites. It is recognized that the concentrations of particulate-associated constituents can vary significantly from the river surface to its bottom because of the sinking of particulate matter and its transport nearer the river bottom. Thus, the calculated flux rates from the near-surface sampling likely under estimate the total phosphorus loadings. The powerplant samples are representative of the water discharged from the dams and give an unbiased estimate of total phosphorus loadings. Loadings for nitrate-nitrite and total nitrogen are believed to be unbiased in this regard as these nitrogen constituents do not tend to be particulate associated.

Figure 6-4 plots the estimated mean daily loads in tons per day at the 16 sites along the Missouri River. The six mainstem reservoirs trap nutrients along the Missouri River and function as nutrient sinks. Nutrient loadings are appreciably reduced immediately downstream of the six Missouri River mainstem reservoirs (Figure 6-4). The increased loading in the Missouri River at Williston, ND is attributed to the inflow of the Yellowstone River which has no major reservoirs along its entire reach to Yellowstone National Park. The greatly increasing nutrient loads in the Missouri River downstream of Gavins Point Dam are attributed to point and nonpoint source nutrient input to the river.

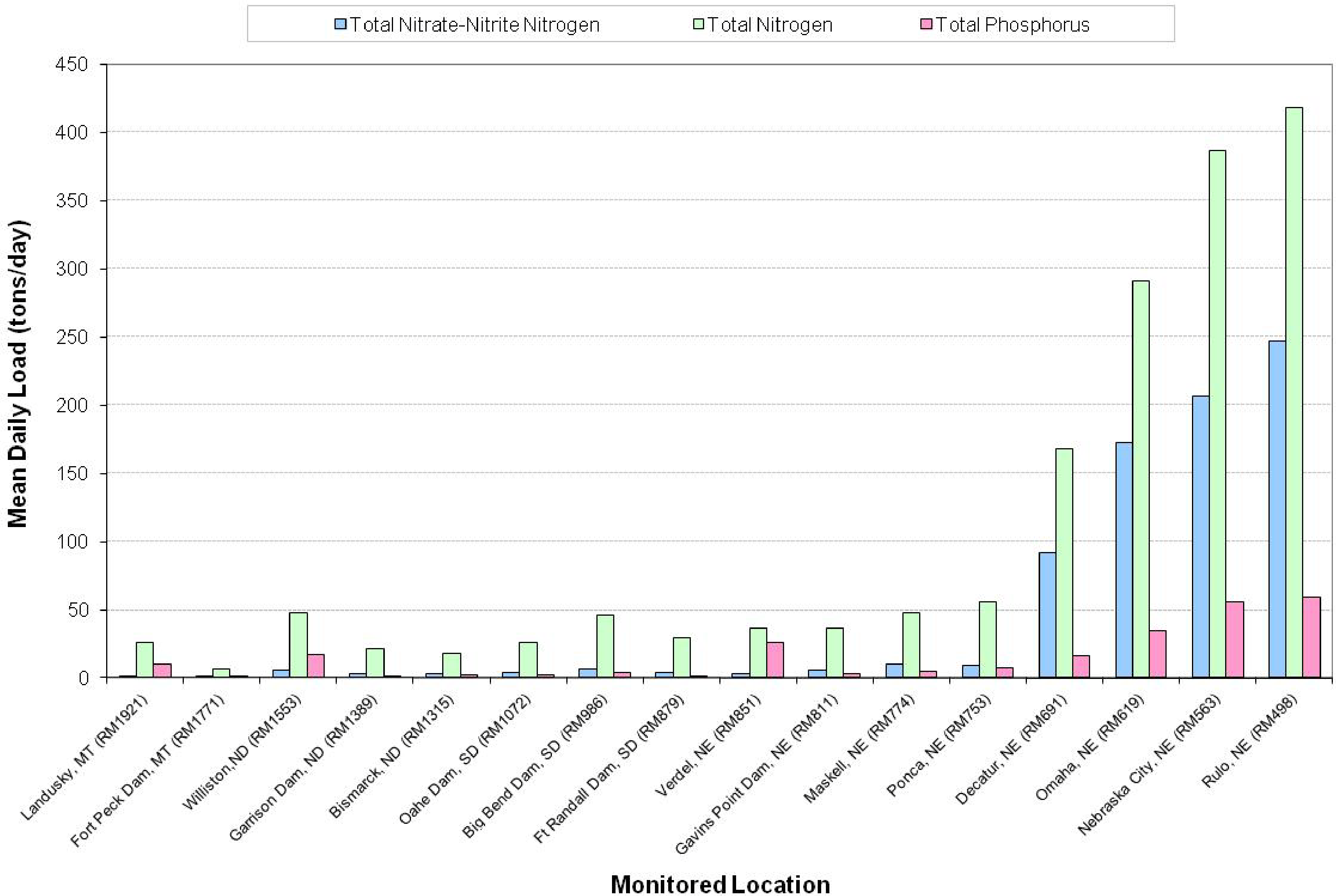

Figure 6-4. Estimated mean daily loads (tons/day) for total nitrate-nitrite nitrogen, total nitrogen, and total phosphorus along the Missouri River from near Landusky, MT (RM1921) to Rulo, NE (RM498) for the 5-year period 2006 through 2010.

7 MAINSTEM ANCILLARY LAKES

7.1 LAKE AUDUBON

7.1.1 BACKGROUND INFORMATION

7.1.1.1 Lake Description

Lake Audubon is a sub-impoundment of Lake Sakakawea that is impounded by the Snake Creek Dam. Lake Audubon is located 12 miles northeast of Garrison Dam near the town of Garrison, ND. The Snake Creek Dam was constructed in 1954 with the primary purpose of relocating transportation and utility services inundated by the creation of Lake Sakakawea. A future purpose of Lake Audubon was to facilitate diversion for the purposes of irrigation, water supply, and pollution abatement. Maintenance of a stable sub-impoundment in the Snake River arm of Lake Sakakawea for wildlife and recreational development was defined as a desirable feature. The Snake River Dam has a crest elevation of 1865 ft-NGVD29, and Lake Audubon pool levels are normally kept at about 1847 ft-NGVD29 in the summer and 1845 ft-NGVD29 in the winter. At pool elevation 1847 ft-NGVD29, Lake Audubon has a surface area of approximately 18,780 acres. The lake is operated in cooperation with the U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, and the North Dakota Game and Fish Department.

7.1.1.2 Water Quality Standards and Section 303(d) Listings

Pursuant to the Federal CWA, the State of North Dakota has designated Lake Audubon as a Class 2 lake. As such, the lake is to be suitable for the propagation and maintenance of a cool-water fishery (i.e., northern pike and walleye) and associated biota; swimming, boating, and other water recreation; irrigation; stock watering; wildlife; and for municipal or domestic use after appropriate treatment. The State of North Dakota has not placed the lake on the State's Section 303(d) list of impaired waters, but has issued a statewide fish consumption advisory, which applies to Lake Audubon, due to mercury concerns.

7.1.1.3 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Lake Audubon since 1980. Figure 7-1 shows the location at Lake Audubon that has been monitored for water quality during the 5-year period 2006 through 2010. The near-dam site was monitored in 2006 and 2009. Water quality monitoring of Lake Audubon is currently on a periodic cycle and it is next scheduled to be monitored in 2013.

7.1.2 EXISTING WATER QUALITY CONDITIONS

7.1.2.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 449 summarizes the water quality conditions that were monitored in Lake Audubon at the near-dam, deepwater ambient monitoring site (i.e., site AUDLKND1) during 2006 and 2009. A review of these results indicated no water quality concerns.

Figure 7-1. Location of water quality monitoring site at Lake Audubon.

7.1.2.2 Summer Thermal Stratification

Existing summer thermal stratification was assessed for Lake Audubon based on monitoring results obtained at the near-dam, deepwater ambient monitoring site (i.e., site AUDLKND1) during 2006 and 2009. Temperature depth profiles were constructed from water quality data collected during the summer months (Plate 450). It appears a temperature-depth gradient occasionally occurs in Lake Audubon in the near-dam lacustrine area during the summer. When temperature stratification occurred, a thermocline was present near the lake bottom. This indicates the reservoir is probably polymixic. During periods of calm weather in the summer, Lake Audubon likely develops a slight thermal stratification. The thermal stratification seemingly breaks down under windier conditions, given the shallow depth of the reservoir (i.e., 16 meters), allowing the reservoir to mix throughout the water column.

7.1.2.3 Summer Dissolved Oxygen Conditions

Existing summer dissolved oxygen conditions were assessed for Lake Audubon based on monitoring results obtained at the near-dam, deepwater ambient monitoring site during 2006 and 2009. Dissolved oxygen depth profiles were constructed from water quality data collected during the summer months (Plate 451). The measured summer dissolved oxygen-depth profiles exhibited some variability with depth. On occasions, low dissolved oxygen concentrations were measured near the reservoir bottom. The variability of the summer dissolved oxygen-depth profiles is attributed to the probable polymictic nature of the lake. When thermal stratification of the reservoir develops in the summer, significant dissolved oxygen degradation occurs in the near-bottom area of the hypolimnion. The lowest dissolved oxygen concentration measured was 1.7 mg/l, and was measured near the reservoir bottom on July 25, 2006.

7.1.2.4 Lake Trophic Status

Trophic State Index (TSI) values for Lake Audubon were calculated from monitoring data collected during 2006 and 2009 at the near-dam, ambient monitoring site (i.e., site AUDLKND1). Table 7-1 summaries the TSI values calculated for the lake. The TSI values indicate that the near-dam lacustrine area of Lake Audubon is in a moderately eutrophic state.

Table 7-1. Summary of Trophic State Index (TSI) values calculated for Lake Audubon for 2006 and 2009.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	8	50	54	37	57
TSI(TP)	9	54	60	41	76
TSI(Chl)	8	49	43	40	50
TSI(Avg)	7	51	52	44	57

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values regardless of the parameters available to calculate the average.

Note: See Section 4.1.4 for discussion of TSI calculation.

7.1.2.5 Impairment of Designated Water Quality Beneficial Uses

Based on the State of North Dakota's impairment assessment methodology (Section 4.1.6.3), the water quality conditions monitored in Lake Audubon during 2006 and 2009 do not indicate any impairment of any designated water quality dependent beneficial uses.

7.1.3 WATER QUALITY TRENDS (1980 THROUGH 2009)

Water quality trends over the 30-year period of 1980 through 2009 were determined for Lake Audubon for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the lake during the months of May through October at the near-dam monitoring site (i.e., site AUDLKND1). Plate 452 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, Lake Audubon exhibited significant trends for chlorophyll *a* (decreasing) and TSI (decreasing). No significant trends were detected for Secchi depth and total phosphorus. Over the 30-year period, the lake has generally remained in a moderately eutrophic state.

7.2 LAKE POCASSE

7.2.1 BACKGROUND INFORMATION

7.2.1.1 Lake Description

Lake Pocasse is a sub-impoundment of Lake Oahe on Spring Creek that is impounded by the Spring Creek Dam. Lake Pocasse is located in Campbell County, SD, near the town of Pollock. The Spring Creek Dam was built in lieu of a road relocation with a bridge spanning Spring Creek. The purpose of the sub-impoundment was to provide lake and marsh habitat for fish and wildlife management on the Spring Creek bottoms within the Lake Oahe pool area. In October 1962, a National Wildlife Refuge was established in the Spring Creek Bottoms, which includes Lake Pocasse. The U.S. Fish and Wildlife Service is responsible for the maintenance and management of wildlife habitat at Lake Pocasse. At the top of the multi-purpose pool (elevation 1614 ft-NGVD29), Lake Pocasse has a surface area of approximately 1,545 acres and a volume of 7,100 acre-feet

7.2.1.2 Water Quality Standards and Section 303(d) Listings

The State of South Dakota has designated the following water quality-dependent beneficial uses for Lake Pocasse in the State's water quality standards: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, fish and wildlife propagation, and stock watering. The State of South Dakota has placed Lake Pocasse on the State's Section 303(d) list of impaired waters. The identified impaired use is immersion recreation, with the impairment due to *E. coli* bacteria. The State has not issued a fish consumption advisory for the lake.

7.2.1.3 Ambient Water Quality Monitoring

The District has not historically monitored water quality conditions at Lake Pocasse. In 2006, the District initiated periodic monitoring to assess water quality conditions at the lake. Low water levels prevented the District from monitoring Lake Pocasse in 2006. The District did conduct water quality monitoring at the lake in 2009, and is planning to again monitor the lake in 2013. Figure 7-2 shows the water quality monitoring location at Lake Pocasse.

Figure 7-2. Location of water quality monitoring site at Lake Pocasse.

7.2.2 EXISTING WATER QUALITY CONDITIONS

7.2.2.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 453 summarizes the water quality conditions that were monitored in Lake Pocasse at the near-dam, deepwater ambient monitoring site (i.e., site POCLKND1) during 2009. A review of these results indicated no exceedances of water quality standards. However, it is noted that the monitored phosphorus levels (i.e., total, dissolved, and ortho-) were extremely high.

7.2.2.2 Summer Thermal Stratification

Existing summer thermal stratification was assessed for Lake Pocasse, based on monitoring results obtained at the near-dam, deepwater ambient monitoring site (i.e., site POCLKND1) during 2009. Temperature depth profiles were constructed from water quality data collected during the summer months (Plate 454). The shallow depth (i.e., < 5 meters) inhibited a significant temperature-depth gradient from forming in Lake Pocasse in the near-dam lacustrine area during the summer.

7.2.2.3 Summer Dissolved Oxygen Conditions

Existing summer dissolved oxygen conditions were assessed for Lake Pocasse based on monitoring results obtained at the near-dam, deepwater ambient monitoring site during 2009. Dissolved oxygen depth profiles were constructed from water quality data collected during the summer months (Plate 455). The measured summer dissolved oxygen-depth profiles exhibited no significant variability with depth.

7.2.2.4 Lake Trophic Status

Trophic State Index (TSI) values for Lake Pocasse were calculated from monitoring data collected during 2009 at the near-dam, ambient monitoring site (i.e., site POCLKND1). Table 7-2 summaries the TSI values calculated for the lake. The TSI values indicate that the near-dam lacustrine area of Lake Audubon is in an extremely hypereutrophic state.

Table 7-2. Summary of Trophic State Index (TSI) values calculated for Lake Pocasse for 2009.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	4	67	68	62	72
TSI(TP)	4	89	89	87	91
TSI(Chl)	4	78	81	64	86
TSI(Avg)	4	78	80	71	82

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values regardless of the parameters available to calculate the average.

Note: See Section 4.1.4 for discussion of TSI calculation.

7.2.2.5 Impairment of Designated Water Quality Beneficial Uses

Based on the State of South Dakota's impairment assessment methodology (Section 4.1.6.4), the water quality conditions monitored in Lake Pocasse during 2009 do not indicate impairment due to exceedances of conventional or toxic parameters. However, the extreme hypereutrophic conditions indicate that eutrophication may be a problem.

7.3 LAKE YANKTON

7.3.1 BACKGROUND INFORMATION

7.3.1.1 Lake Description

Lake Yankton is an "oxbow" lake of the Missouri River that straddles the Nebraska and South Dakota border, just downstream of Gavins Point Dam. The lake was formed when the Gavins Point Dam embankment and the training dike downstream of the dam's outlet were constructed and cutoff a portion of the Missouri River channel. Lake Yankton has a surface area of approximately 250 acres.

7.3.1.2 Water Quality Standards and Section 303(d) Listings

Pursuant to the Federal Clean Water Act, the State of South Dakota has designated the following water quality-dependent beneficial uses for Lake Yankton: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, fish and wildlife propagation, and stock watering. The State of Nebraska has designated the following beneficial uses to Lake Yankton: primary contact recreation, Class I warmwater aquatic life, agricultural water supply, and aesthetics. The uses designated by the States of South Dakota and Nebraska to Lake Yankton are consistent with each other. Neither of the two States has placed Lake Yankton on the State's Section 303(d) list of impaired waters, or has issued fish consumption advisories for the lake.

7.3.1.3 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Lake Yankton since 1982. Figure 7-3 shows the locations at Lake Yankton that have been monitored for water quality. The deepwater site (YAKLKND1) was monitored monthly (May - September) in 2006 and 2009. The bacteria site (YAKBACT1) was monitored weekly (May - September) during the 5-year period 2006 through 2010.

7.3.2 EXISTING WATER QUALITY CONDITIONS

7.3.2.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 456 summarizes the water quality conditions that were monitored in Lake Yankton at the deepwater ambient monitoring site (i.e., site YAKLKND1) during 2006 and 2009. Based on the criteria for the protection of warmwater aquatic life, 38% of the observations did not meet the dissolved oxygen criterion. The dissolved oxygen measurements that were below the 5.0 mg/l criterion occurred near the lake bottom in the hypolimnion during the summer on occasions when the lake was thermally stratified. Nebraska's dissolved oxygen criteria are not applicable to the hypolimnion when lakes are thermally stratified. The pesticides atrazine and chlorpyrifos were detected on one occasion at levels above State water quality standards criteria.

7.3.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification was assessed for Lake Yankton, based on monitoring results obtained at the deepwater ambient monitoring site (i.e., site YAKLKND1) during 2006 and 2009. Temperature depth profiles were constructed from water quality data collected during the summer months (Plate 457). Summer thermal stratification appears to be present in Lake Yankton, with water temperatures near the lake bottom being up to 10°C cooler then at the lake surface. The cooler water temperatures near the lake bottom are attributed to groundwater inflow to the lake from "relief wells" along Gavins Point Dam.

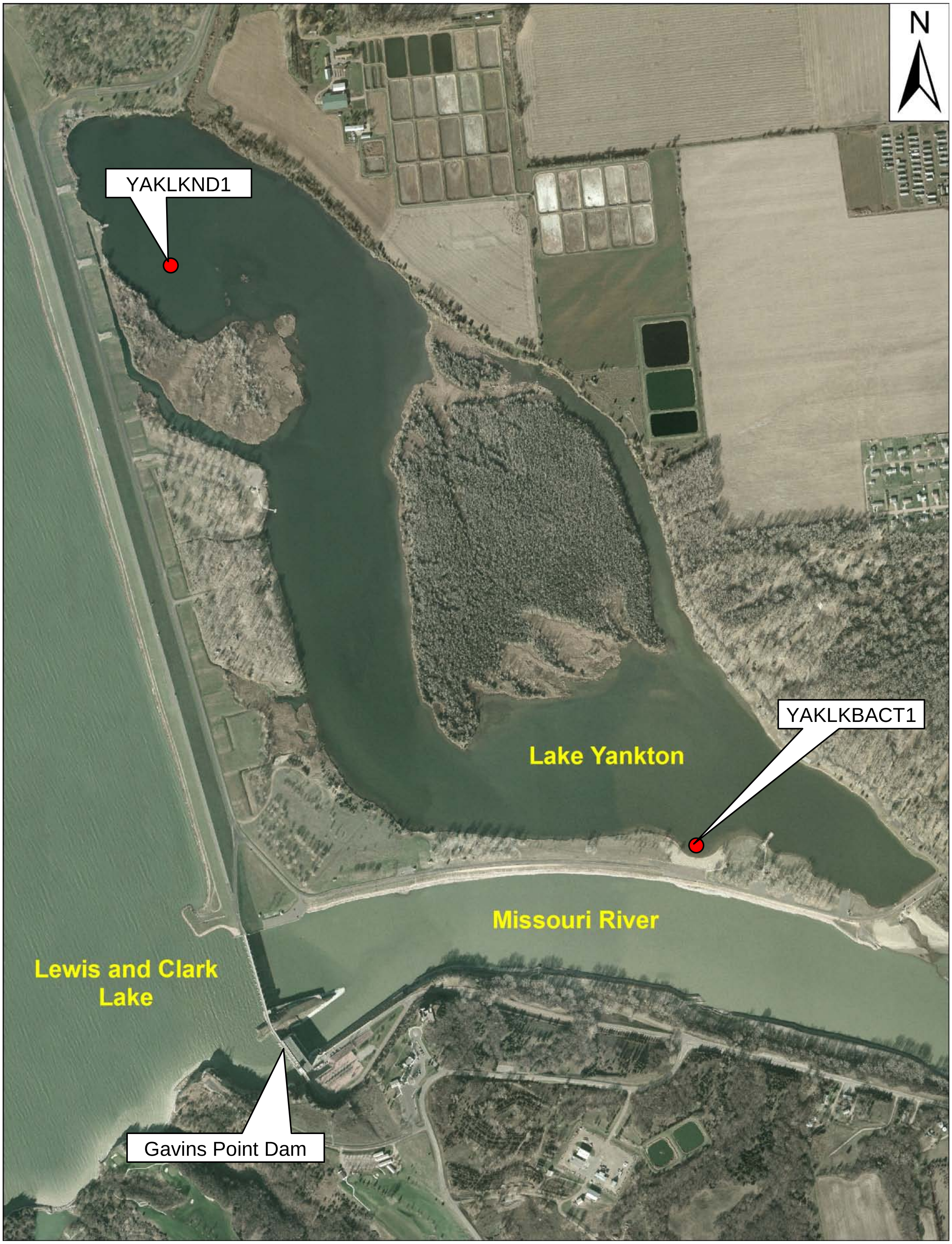

Figure 7-3. Location of water quality monitoring sites on Lake Yankton.

7.3.2.3 Near-Dam Dissolved Oxygen Depth Profile Plots

Existing summer dissolved oxygen conditions were assessed for Lake Yankton based on monitoring results obtained at the deepwater ambient monitoring site during 2006 and 2009. Dissolved oxygen depth profiles were constructed from water quality data collected during the months of June, July, August, and September (Plate 458). The measured summer dissolved oxygen-depth profiles exhibited extreme variability with depth. Dissolved oxygen concentrations consistently fell below 1 mg/l in the bottom 1 to 2 meters of the lake. The lowest dissolved oxygen concentration measured was 0.2 mg/l.

7.3.2.4 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Lake Yankton during the summer in 2006 and 2009 were compared. Near-surface conditions were represented by samples collected within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 1-meter of the reservoir bottom. The compared samples were collected at site YAKLKND1. During the period a total of 4 to 8 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total ammonia, total phosphorus, total iron, and total manganese (Plate 459). The box plots show observable differences between surface and bottom conditions for several parameters. A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for water temperature, dissolved oxygen, ORP, pH, alkalinity, and total iron. Parameters that were significantly lower in the near-bottom water of Lake Yankton included: water temperature ($p < 0.01$), dissolved oxygen ($p < 0.001$), ORP ($p < 0.05$), and pH ($p < 0.001$). Parameters that were significantly higher in the near-bottom water included: alkalinity ($p < 0.05$) and total iron ($p < 0.05$). Small sample size and high variability limited significance testing for total ammonia and total manganese.

7.3.2.5 Lake Trophic Status

Trophic State Index (TSI) values for Lake Yankton were calculated from monitoring data collected during the 2006 and 2009 at the deepwater ambient monitoring site (i.e., site YAKLKND1). Table 7-3 summaries the TSI values calculated for the lake. The TSI values indicate that the Lake Yankton is in a eutrophic state.

Table 7-3. Summary of Trophic State Index (TSI) values calculated for Lake Yankton for 2006 and 2009.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	10	60	58	52	77
TSI(TP)	10	53	50	41	72
TSI(Chl)	10	58	57	40	79
TSI(Avg)	10	57	58	48	63

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values the parameters available to calculate the average.

Note: See Section 4.1.4 for discussion of TSI calculation.

7.3.2.6 Bacteria Monitoring at the Training Dike Swimming Beach at Lake Yankton

During the 5-year period 2006 through 2010, bacteria samples were collected weekly from May through September at the Training Dike swimming beach located on Lake Yankton. Table 7-4 summarizes the results of the bacteria sampling. The geometric means were calculated as running geometric means for five consecutive weekly bacteria samples and nondetects were set to 1. The bacteria sampling results were compared to following bacteria criteria for support of "full-body contact" recreation:

Fecal Coliform:

Bacteria of the fecal coliform group should not exceed a geometric mean of 200/100ml, nor equal or exceed 400/100ml, in more than 10% of the samples. These criteria are based on a minimum of five samples taken within a 30-day period.

E. coli:

E. coli bacteria should not exceed a geometric mean of 126/100ml. For increased confidence of the criteria, the geometric mean should be based on a minimum of five samples taken within a 30-day period. Single sample maximum allowable density for designated bathing beaches is 235/100ml.

Based on these criteria and Nebraska's impairment assessment methodology (Section 4.1.6.2.2), "full-body contact" recreation was fully supported at the Training Dike swimming beach on Lake Yankton during the May through September recreational season during the 5-year period of 2006 through 2010.

Table 7-4. Summary of weekly (May through September) bacteria sampling conducted at the Training Dike swimming beach on Lake Yankton during the 5-year period 2006 through 2010.

	Fecal Coliform Bacteria	***E. coli* Bacteria**
Number of Samples	106	106
Mean	17	20
Median	6	4
Minimum	n.d.	n.d.
Maximum	210	357
Percent of Fecal Coliform samples exceeding 400/100ml	0%	-----
Percent of *E. coli* samples exceeding 235/100ml	-----	2%
• **Geometric Mean**		
Number of Geomeans	87	87
Average	9	9
Median	6	5
Minimum	2	1
Maximum	58	64
Number of Fecal Coliform geomeans exceeding 200/100ml	0	-----
Number of *E. coli* geomeans exceeding 126/100ml	-----	0

n.d. = Not detected.
Note: Not detected values set to 1 to calculate mean and geometric mean.

7.3.2.7 Impairment of Designated Water Quality Beneficial Uses

Based on the States of Nebraska and South Dakota impairment assessment methodologies (Sections 4.1.6.2 and 4.1.6.4), the water quality conditions monitored in Lake Yankton during 2006 and 2009 do not indicate impairment of any designated water quality dependent beneficial uses.

7.3.3 WATER QUALITY TRENDS (1980 THROUGH 2009)

Water quality trends over the period of 1982 through 2009 were determined for Lake Yankton for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the lake during the months of May through October at the deepwater site (i.e., site YAKLKND1). Plate 460 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, Lake Yankton exhibited significant trends for Secchi depth (decreasing) and TSI (increasing). No significant trends were detected for total phosphorus and chlorophyll *a*. Over the 25-year period, the lake has generally moved from a moderately eutrophic to a eutrophic state.

8 WATER QUALITY MONITORING AND MANAGEMENT ACTIVITIES PLANNED FOR FUTURE YEARS

8.1 WATER QUALITY DATA COLLECTION

A tentative schedule of water quality monitoring targeted for implementation over the next 5 years is given in Table 8-1. The identified data collection activities are considered the minimum needed to allow for the annual assessment of water quality conditions at District projects and the preparation of water quality reports and water quality management objectives for the Mainstem System Projects. The actual monitoring activities that are implemented will be dependent upon the availability of future resources.

8.2 PROJECT-SPECIFIC WATER QUALITY MANAGEMENT PLANNING

Corps guidance for water quality and environmental management at civil works projects (USACE, 1995) identifies the need to develop specific water quality management objectives for each project and to outline procedures to be implemented to meet those objectives. The identified objectives and procedures are to be included in the project water control plans. The water quality management objectives are to be reviewed and updated as needed, but at least every 10 years.

The Omaha District's intent is to develop water quality management objectives for Mainstem System project based on the findings presented in project water quality reports. Therefore, it is important that the water quality reports for a project be updated prior to the development or update of the water quality management objectives for the project. This will ensure that the water quality management objectives for the projects address all of the known surface water quality issues and concerns. Where data are lacking or water quality issues need to be further evaluated, monitoring should be implemented to address these data needs and the collected information included in Project water quality reports. Water quality management objectives will be developed in coordination with project operations staff and, as appropriate, the Northwestern Division's Missouri River Basin Water management Division (MRBWMD). The project water quality management objectives will be provided to the District's Engineering and Operation Divisions and the MRBWMD for incorporation into Project Water Control Manuals and Master Plans.

The CE-QUAL-W2 hydrodynamic and water quality model is being applied to facilitate the development of Project water quality reports and project-specific water quality management objectives. The tentative schedule for implementing these water-quality management planning activities on the Mainstem System projects is given in Table 8-2.

8.3 TOTAL MAXIMUM DAILY LOADS (TMDLS)

The District will participate, as appropriate, as a stakeholder in the development and implementation of TMDLs on waterbodies that involve District projects.

Table 8-1. Water quality monitoring planned by the District at Missouri River Mainstem System Projects for the next 5 years and the intended data collection approach. Actual monitoring activities implemented will be dependent upon available resources.

Mainstem Project Areas to be Monitored	**Long-Term Fixed Station Monitoring**	**Intensive Surveys**	**Special Studies**	**Investigative Monitoring**
• Fort Peck		*	X[c]	X[d]
- Fort Peck Lake (3 Sites: Near-dam, Hell Creek, and Rock Creek)	X[a]			
- Missouri River Inflow to Fort Peck Lake (near Landusky, MT)	X[a]			
- Fort Peck Powerplant ("Raw-Water" Supply Line)	X[a]			
• Garrison		*		X[d]
- Lake Sakakawea (5 Sites: Near-dam, Beulah Bay, Deepwater Bay, New Town, White Tail Bay)	X[a]			
- Missouri River Inflow to Lake Sakakawea (near Williston, ND)	X[a]			
- Garrison Powerplant ("Raw-Water" Supply Line)	X[a]			
- Lake Audubon	2013, 2016			
• Oahe		*		X[d]
- Lake Oahe (5 Sites: Near-dam, Little Bend, Whitlocks Bay, Mobridge, Beaver Creek)	X[a]			
- Missouri River Inflow to Lake Oahe (near Bismarck, ND)	X[a]			
- Oahe Powerplant ("Raw-Water" Supply Line)	X[a]			
- Lake Pocasse	2013, 2016			
• Big Bend		*		
- Lake Sharpe (3 Sites: Near-dam, Iron Nation, Antelope Creek)	X[a]			
- Big Bend Powerplant ("Raw-Water" Supply Line)	X[a]			
• Fort Randall		*		X[d]
- Lake Francis Case (4 Sites: Near-dam, Platte Creek, Elm Creek, Chamberlain)	X[a]			
- Fort Randall Powerplant ("Raw-Water" Supply Line)	X[a]			
• Gavins Point	X[a]	*		X[d]
- Lewis and Clark Lake (3 Sites: Near-dam, Bloomfield, Charley Creek)	X[a]			
- Missouri River Inflow to Lewis and Clark Lake (near Running Water, SD)				
- Gavins Point Powerplant ("Raw-Water" Supply Line)	X[a]			
- Lake Yankton	2013, 2016			
• Missouri River – Fort Randall Dam to Lewis and Clark Lake (3 Sites: Fort Randall Dam Tailwaters, RM851, and RM841)	X[b]			X[d]
• Missouri River – Gavins Point Dam to Rulo, Nebraska (7 Sites: Gavins Point Tailwaters, RM774, RM753, RM691, RM619, RM563, and RM498).	X[b]	2010-2013[e]		X[d]

* A 3-year intensive survey was completed at Garrison in 2005, Fort Peck in 2006, Oahe in 2007, Fort Randall in 2008, Big Bend in 2010, and Gavins Point in 2010.

a To be monitored every year.

b Six sites (RM851, RM774, RM691, RM619, RM563, and RM498) are being monitored under an Interagency Support Agreement with the Nebraska Department of Environmental Quality.

c Special Study will be implemented, as necessary, to facilitate application of a Scoping Study to evaluate the feasibility of constructing a "multi-level" intake structure at Fort Peck Dam to allow better management of the water temperature of water discharged through the Fort Peck powerplant.

d Investigative Monitoring will be conducted as necessary and appropriate.

e A joint intensive water quality survey is being implemented with the Kansas City District to monitoring water quality along the Missouri River from Gavins Point Dam to the river's mouth at St. Louis, MO.

Table 8-2. Tentative schedule for water quality management planning activities for the Mainstem System Projects.

Planning Activity	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point	Missouri River*
Ambient water quality monitoring	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing
Conduct 3-year intensive water quality survey	Completed (2006)	Completed (2005)	Completed (2007)	Completed (2010)	Completed (2008)	Completed (2010)	2010-13
Prepare Water Quality Special Study Report (Findings of the 3-year intensive water quality survey)	Completed (2007)	Completed (2006)	Completed (2008)	2011	Completed (2009)	2011	2014
Application of CE-QUAL-W2 hydrodynamic and water quality model	2009	Completed (2008) Currently being Updated	2011/2012	2014	2012/13	2014	2014
Prepare Water Quality Special Study Report (Application of the CE-QUAL-W2 Model)	2009	2008 (Updated Report) (2011)	2012	2014	2013	2014	2014
Prepare Project-Specific Water Quality Report	2013	2012	2014	2018	2015	2017	2016
Develop project-specific water quality management objectives	2013	2012	2014	2018	2015	2017	2016

* Downstream of Gavins Point Dam.

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10 PLATES

Plate 1. Summary of monthly (May through September) water quality conditions monitored in Fort Peck Lake near Fort Peck Dam (Site FTPLK1772A) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	25	2212.8	2209.3	2198.7	2235.8	-----	-----	-----
Water Temperature (°C)	0.1	1,341	12.2	11.7	4.0	25.5	26.7[1,2]	0	0%
Dissolved Oxygen (mg/l)	0.1	1,341	9.0	8.9	5.2	12.2	5.0[1,3]	0	0%
Dissolved Oxygen (% Sat.)	0.1	1,297	86.0	89.9	49.9	104.4	-----	-----	-----
Specific Conductance (umhos/cm)	1	1,297	535	5.9	466	561	-----	-----	-----
pH (S.U.)	0.1	1,297	8.2	8.2	7.4	8.8	6.5[1,3], 9.0[1,2]	0	0%
Turbidity (NTUs)	1	1,246	-----	8.2	7.4	8.8	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	1,297	335	335	204	526	-----	-----	-----
Secchi Depth (in.)	1	25	130	131	56	216	-----	-----	-----
Alkalinity, Total (mg/l)	7	50	150	151	140	170	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	48	2.5	2.5	n.d.	4.9	-----	-----	-----
Chemical Oxygen Demand, Total (mg/l)	2	50	7	8	n.d.	17	-----	-----	-----
Chloride (mg/l)	1	40	9	9	7	10	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Measured	1	988	4	2	n.d.	22	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	25	3	2	n.d	10	-----	-----	-----
Color (APHA)	1	10	3	3	n.d	6	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	50	359	347	260	582	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	50	-----	n.d.	n.d.	0.58	3.8[1,2,4], 1.7[1,4,5]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	50	0.3	0.3	n.d.	1.4	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	50	-----	n.d.	n.d.	0.15	-----	-----	-----
Nitrogen, Total (mg/l)	0.1	50	0.4	0.3	n.d.	1.4	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	50	-----	0.01	n.d.	0.11	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	50	0.03	0.02	n.d.	0.27	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	50	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	50	122	122	98	132	-----	-----	-----
Suspended Solids, Total (mg/l)	4	50	-----	n.d.	n.d.	14	-----	-----	-----
Microcystin, Total (ug/l)	0.2	25	-----	n.d.	n.d.	0.4	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for B-3 classified waters.

(2) Daily maximum criterion (monitoring results directly comparable to criterion).

(3) Daily minimum criterion (monitoring results directly comparable to criterion).

(4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(5) 30-day average criterion (monitoring results not directly comparable to criterion).

Plate 2. Summary of monthly (June through September) water quality conditions monitored in Fort Peck Lake near Hell Creek Bay (site FTPLK1805DW) during the 5-year period 2006 through 2010.

	Monitoring Results[A]						Water Quality Standards Attainment		
Parameter	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	20	2214.3	2209.7	2198.7	2235.8	-----	-----	-----
Water Temperature (°C)	0.1	547	15.0	15.4	5.5	27.4	26.7[1,2]	1	<1%
Dissolved Oxygen (mg/l)	0.1	547	8.3	8.5	3.7	12.2	5.0[1,3]	28	5%
Dissolved Oxygen (% Sat.)	0.1	527	84.6	88.9	38.1	121.2	-----	-----	-----
Specific Conductance (umhos/cm)	1	527	528	563	461	574	-----	-----	-----
pH (S.U.)	0.1	527	8.2	8.3	7.1	9.1	6.5[1,3], 9.0[1,2]	15	3%
Turbidity (NTUs)	1	504	-----	1	n.d.	21	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	527	312	304	182	464	-----	-----	-----
Secchi Depth (in)	1	20	98	93	46	150	-----	-----	-----
Alkalinity, Total (mg/l)	7	40	146	146	139	170	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	38	2.7	2.6	n.d.	5.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	40	8	9	n.d.	18	-----	-----	-----
Chloride (mg/l)	1	30	8	8	4	10	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Measured	1	427	6	5	n.d.	26	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	20	5	5	n.d.	18	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	40	343	342	252	558	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	40	-----	n.d.	n.d.	0.14	3.1 [1,2,4], 1.4[1,4,5]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	40	0.3	0.3	n.d.	1.1	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	40	-----	n.d.	n.d.	0.16	-----	-----	-----
Nitrogen, Total (mg/l)	0.1	40	0.4	0.3	n.d.	1.1	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	40	-----	n.d.	n.d.	0.06	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	40	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	40	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	40	119	120	85	137	-----	-----	-----
Suspended Solids, Total (mg/l)	4	40	-----	n.d.	n.d.	8	-----	-----	-----
Microcystin (ug/l)	0.2	19	-----	n.d.	n.d.	0.3	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for B-3 classified waters.
- (2) Daily maximum criterion (monitoring results directly comparable to criterion).
- (3) Daily minimum criterion (monitoring results directly comparable to criterion).
- (4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (5) 30-day average criterion (monitoring results not directly comparable to criterion).

Plate 3. Summary of monthly (June through September) water quality conditions monitored in Fort Peck Lake near Rock Creek Bay (site FTPLKBDCA02) during the 5-year period 2006 through 2010.

	Monitoring Results[A]						Water Quality Standards Attainment		
Parameter	**Detection Limit[B]**	**No. of Obs.**	**Mean[C]**	**Median**	**Min.**	**Max.**	**State WQS Criteria[D]**	**No. of WQS Exceedances**	**Percent WQS Exceedance**
Pool Elevation (ft-NGVD29)	0.1	23	2213.7	2209.5	2198.7	2235.8	-----	-----	-----
Water Temperature (°C)	0.1	469	16.0	17.1	5.1	24.2	26.7[1,2]	0	0%
Dissolved Oxygen (mg/l)	0.1	469	8.9	8.7	6.1	11.7	5.0[1,3]	0	0%
Dissolved Oxygen (% Sat.)	0.1	455	93.0	94.6	66.4	105.3	-----	-----	-----
Specific Conductance (umhos/cm)	1	455	545	546	500	580	-----	-----	-----
pH (S.U.)	0.1	455	8.4	8.5	7.8	8.9	6.5[1,3], 9.0[1,2]	0	0%
Turbidity (NTUs)	1	452	-----	1	n.d.	16	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	455	316	310	187	492	-----	-----	-----
Secchi Depth (in)	1	23	120	120	26	240	-----	-----	-----
Alkalinity, Total (mg/l)	7	31	148	149	140	157	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	30	2.7	2.5	n.d.	4.9	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	31	7	8	n.d.	15	-----	-----	-----
Chloride (mg/l)	1	22	9	9	7	10	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Measured	1	350	4	3	1	19	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	21	3	2	n.d.	12	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	31	357	350	268	550	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	31	-----	n.d.	n.d.	0.09	2.1 [1,2,4], 0.9[1,4,5]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	31	0.3	0.2	n.d.	1.5	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	31	-----	n.d.	n.d.	0.46	-----	-----	-----
Nitrogen, Total (mg/l)	0.1	31	0.3	0.3	n.d.	1.5	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	31	-----	n.d.	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	31	-----	0.02	n.d.	0.06	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	31	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	31	125	125	110	133	-----	-----	-----
Suspended Solids, Total (mg/l)	4	31	-----	n.d.	n.d.	5	-----	-----	-----
Microcystin (ug/l)	0.2	21	-----	n.d.	n.d.	0.4	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for B-3 classified waters.
(2) Daily maximum criterion (monitoring results directly comparable to criterion).
(3) Daily minimum criterion (monitoring results directly comparable to criterion).
(4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(5) 30-day average criterion (monitoring results not directly comparable to criterion).

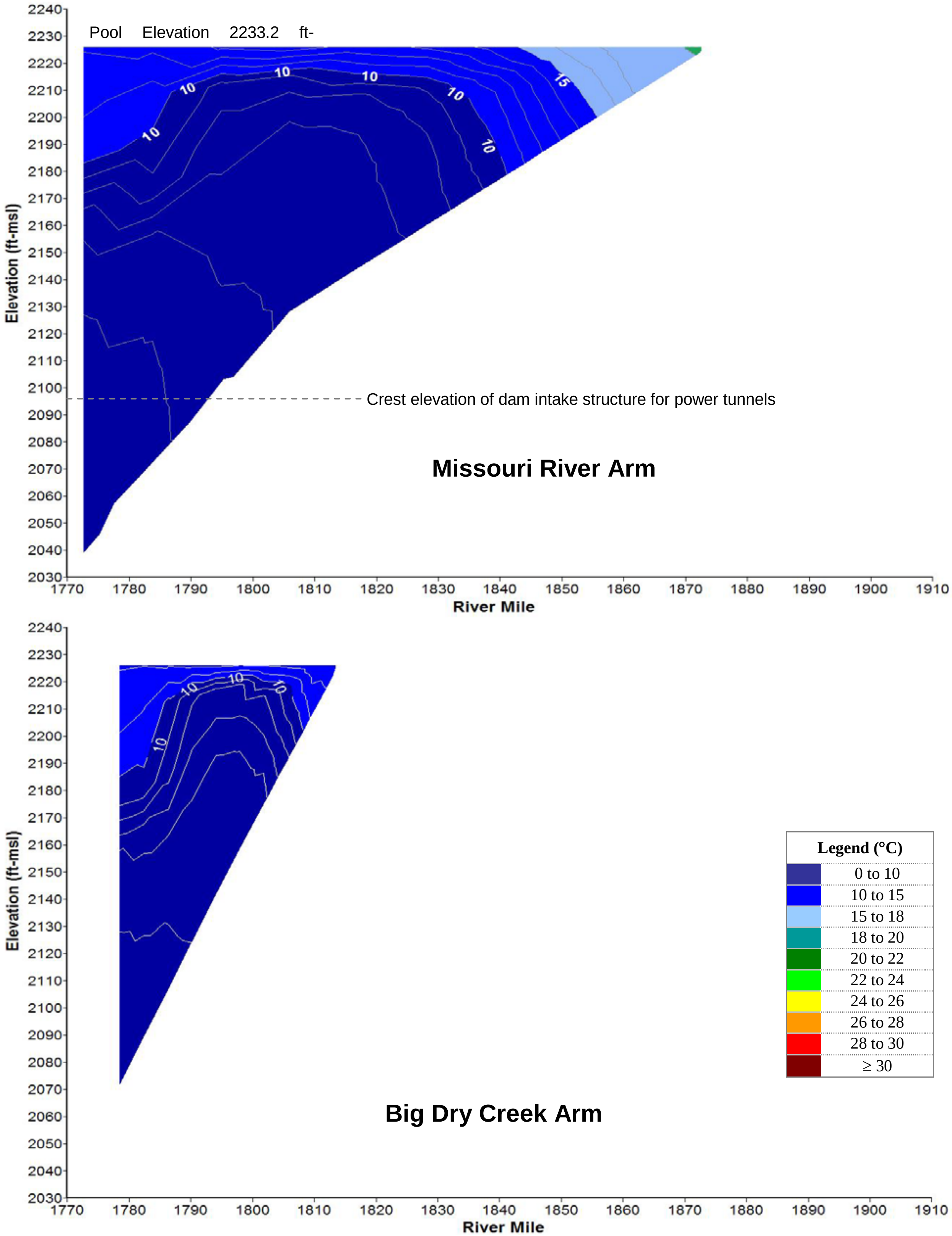

Plate 4. Longitudinal water temperature (°C) contour plot of Fort Peck Lake based on depth-profile water temperatures measured at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on May 19, 2010.

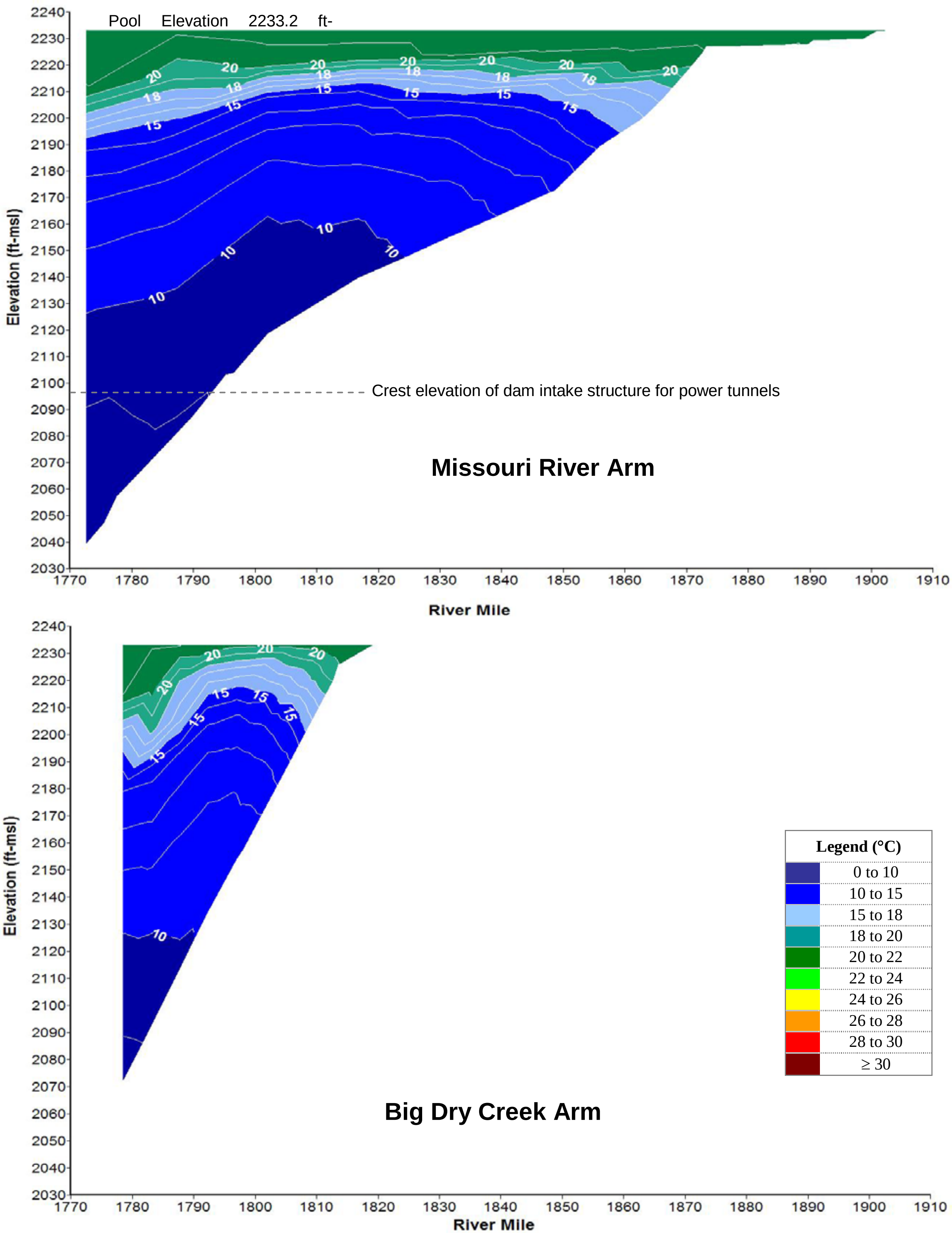

Plate 5. Longitudinal water temperature (°C) contour plot of Fort Peck Lake based on depth-profile water temperatures measured at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on June 30, 2010.

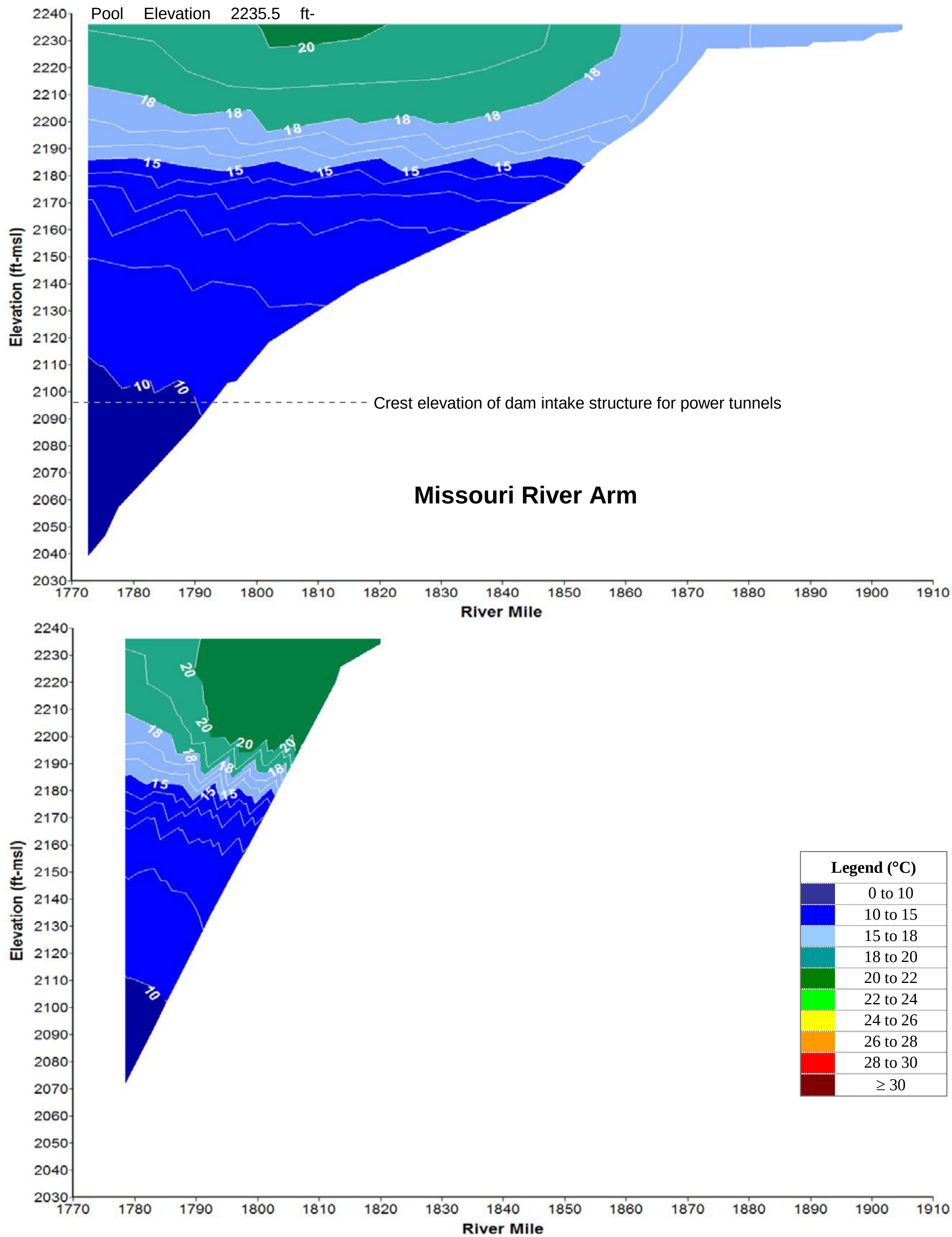

Plate 6. Longitudinal water temperature (°C) contour plot of Fort Peck Lake based on depth-profile water temperatures measured at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on July 21, 2010.

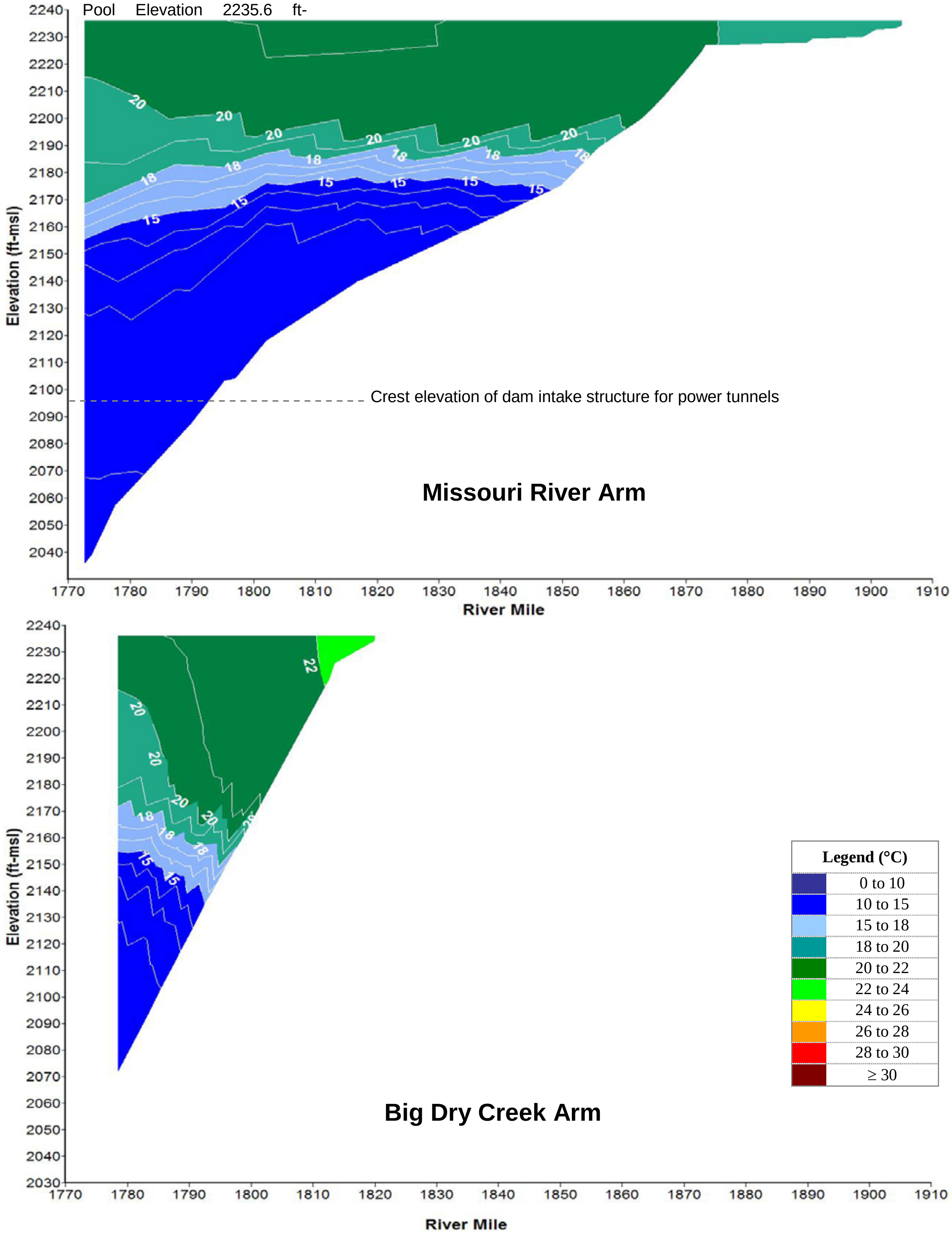

Plate 7. Longitudinal water temperature (°C) contour plot of Fort Peck Lake based on depth-profile water temperatures measured at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on August 24, 2010.

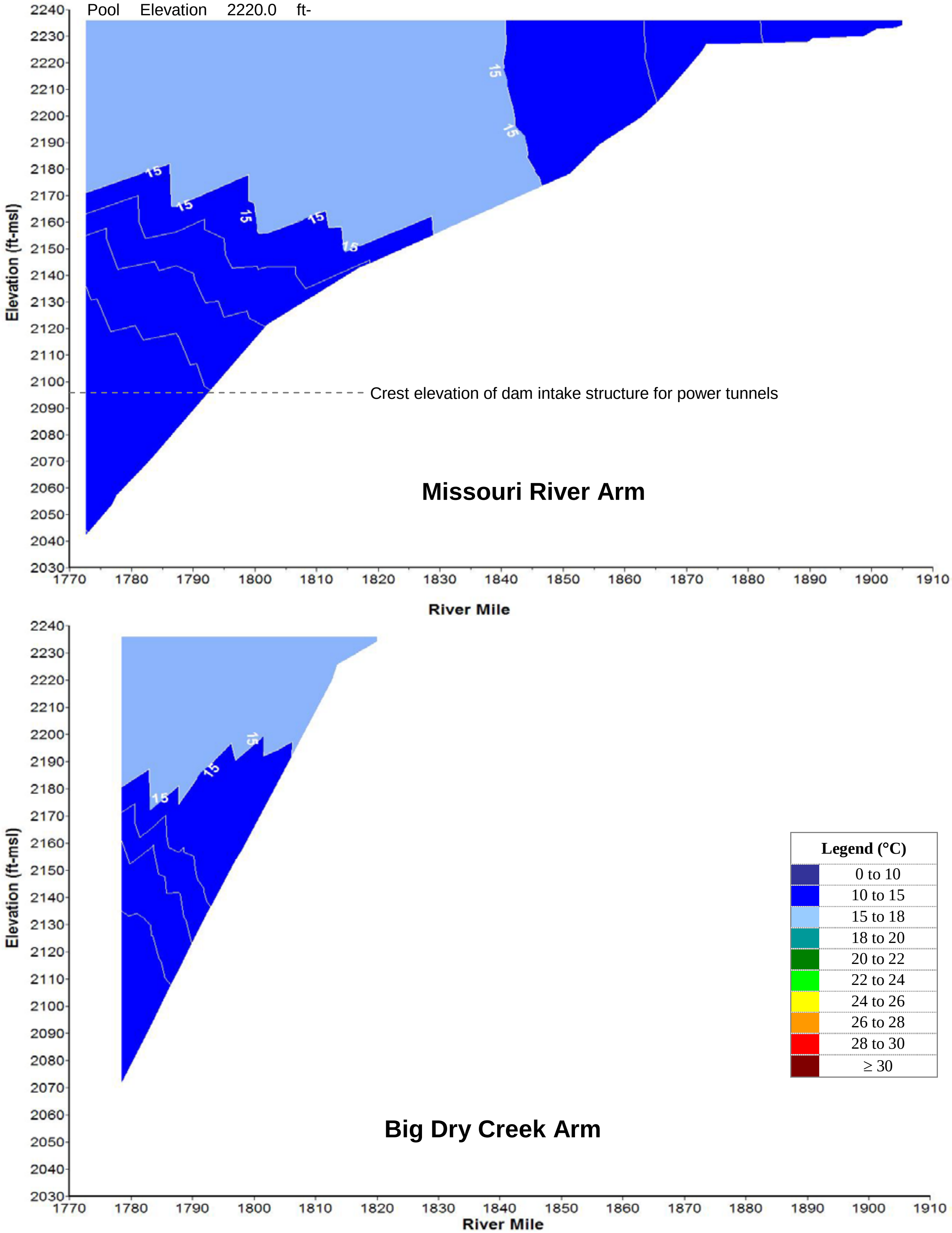

Plate 8. Longitudinal water temperature (°C) contour plot of Fort Peck Lake based on depth-profile water temperatures measured at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on September 22, 2010.

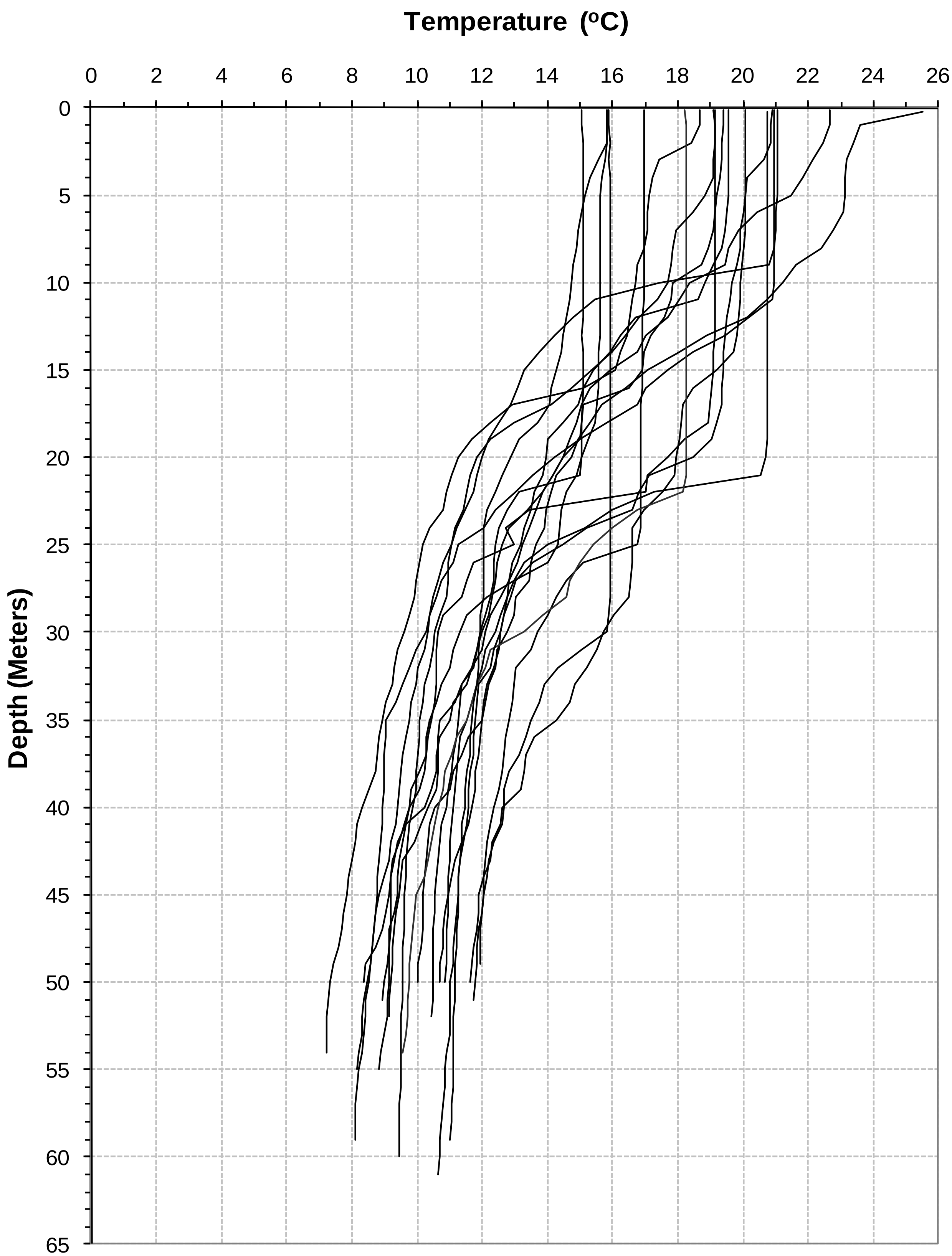

Plate 9. Temperature depth profiles for Fort Peck Lake compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., FTPLK1772A) during the summer over the 5-year period of 2006 to 2010.

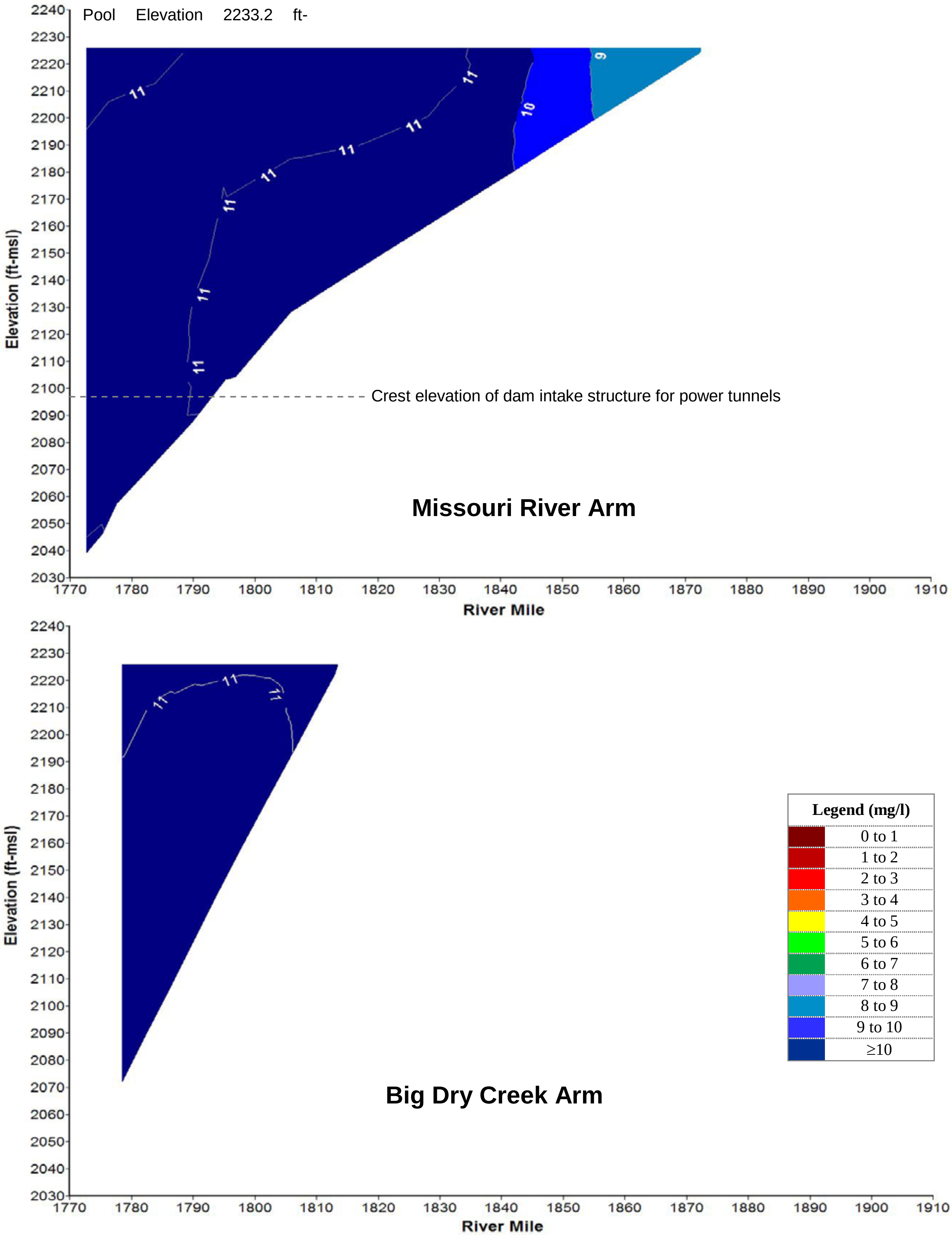

Plate 10. Longitudinal dissolved oxygen (mg/l) contour plot of Fort Peck Lake based on depth-profile dissolved oxygen concentrations monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on May 19, 2010.

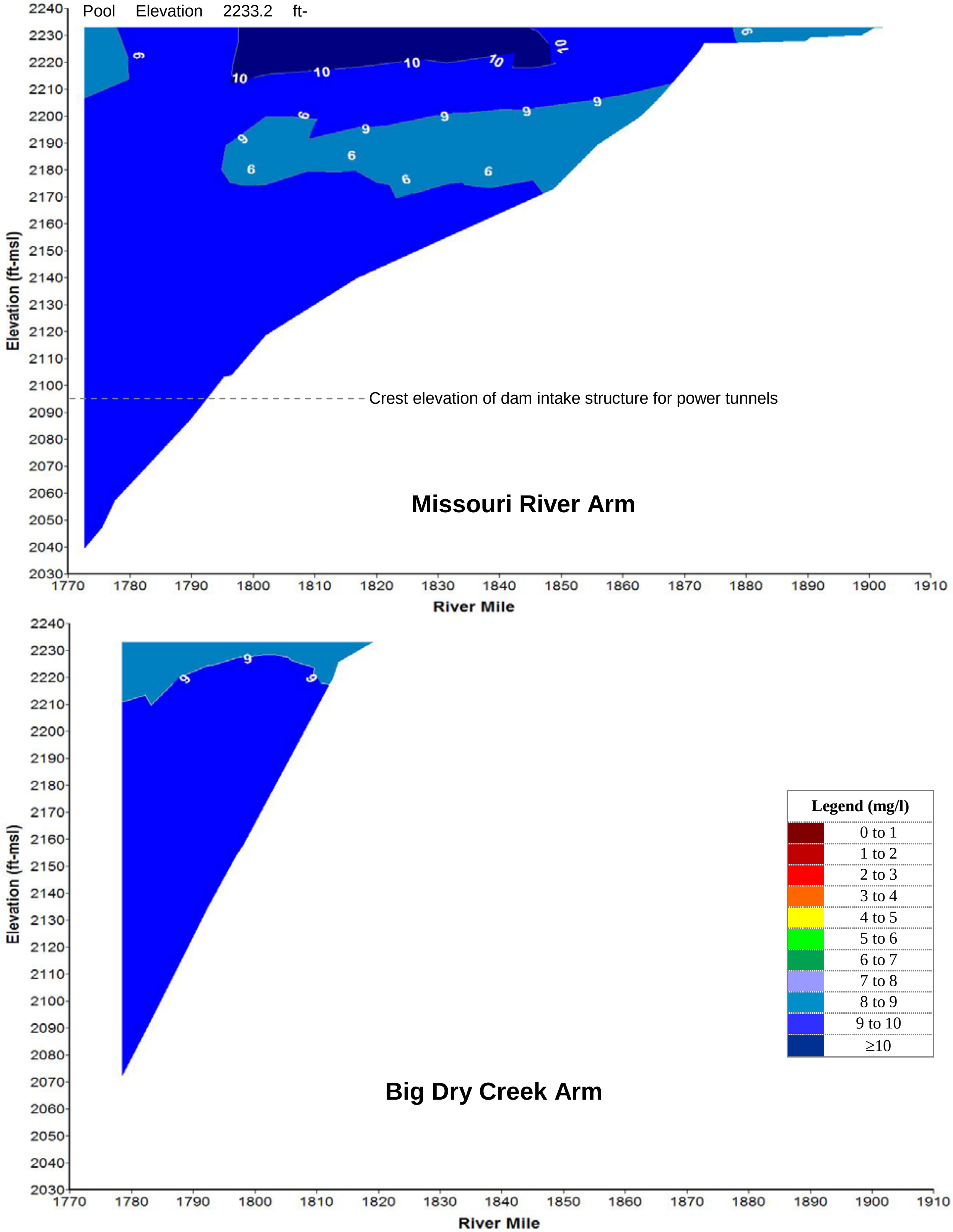

Plate 11. Longitudinal dissolved oxygen (mg/l) contour plot of Fort Peck Lake based on depth-profile dissolved oxygen concentrations monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on June 30, 2010.

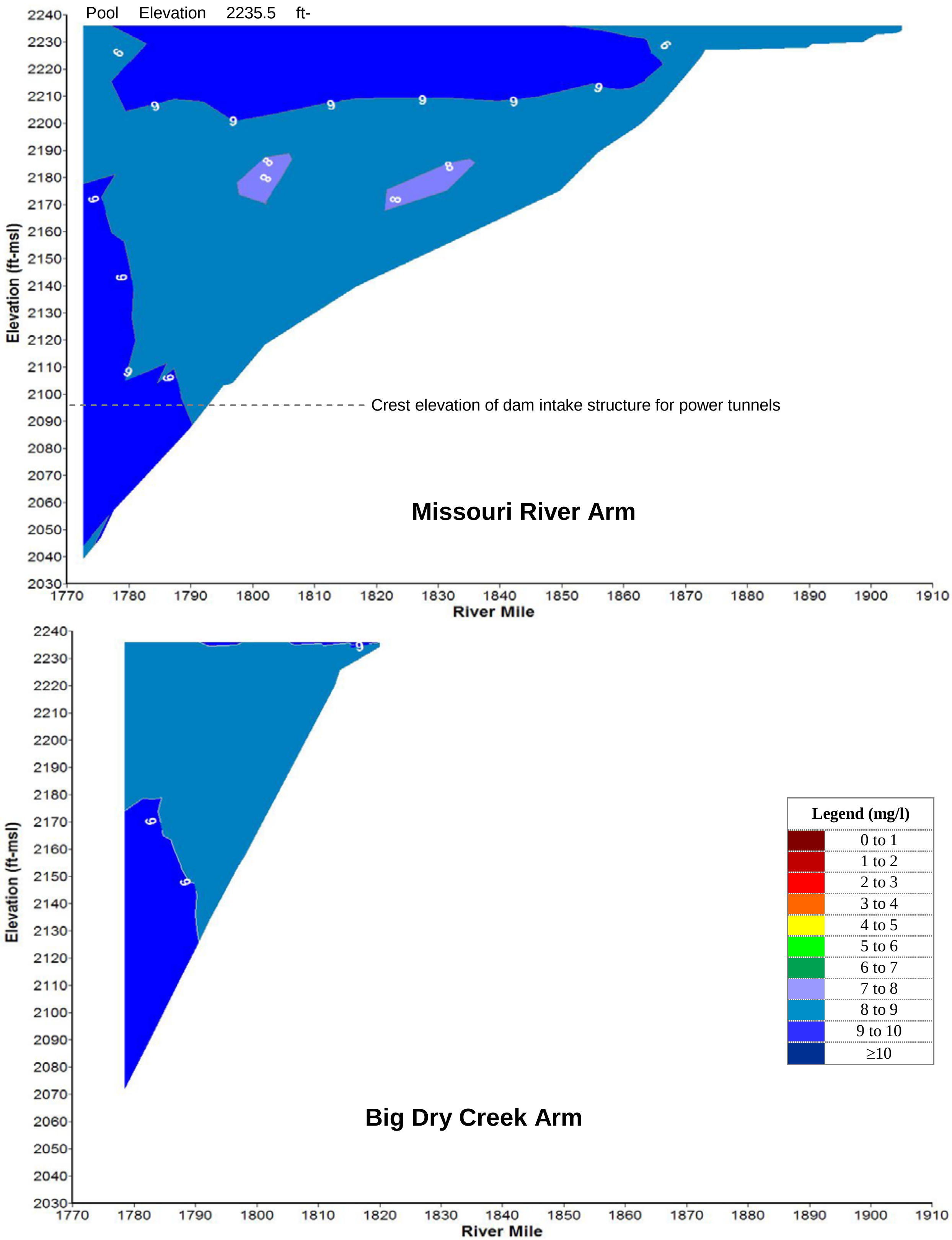

Plate 12. Longitudinal dissolved oxygen (mg/l) contour plot of Fort Peck Lake based on depth-profile dissolved oxygen concentrations monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on July 21, 2010.

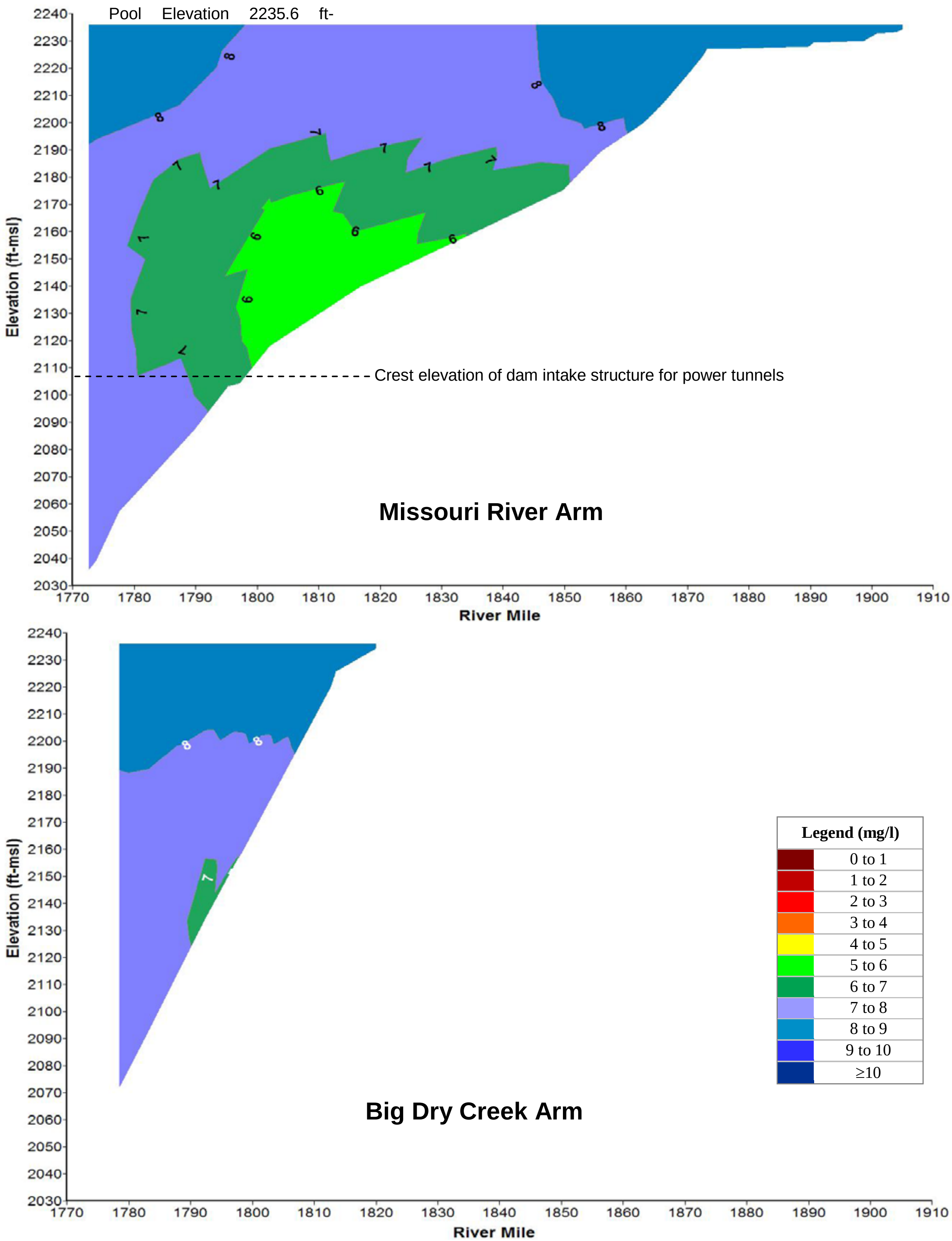

Plate 13. Longitudinal dissolved oxygen (mg/l) contour plot of Fort Peck Lake based on depth-profile dissolved oxygen concentrations monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on August 24, 2010.

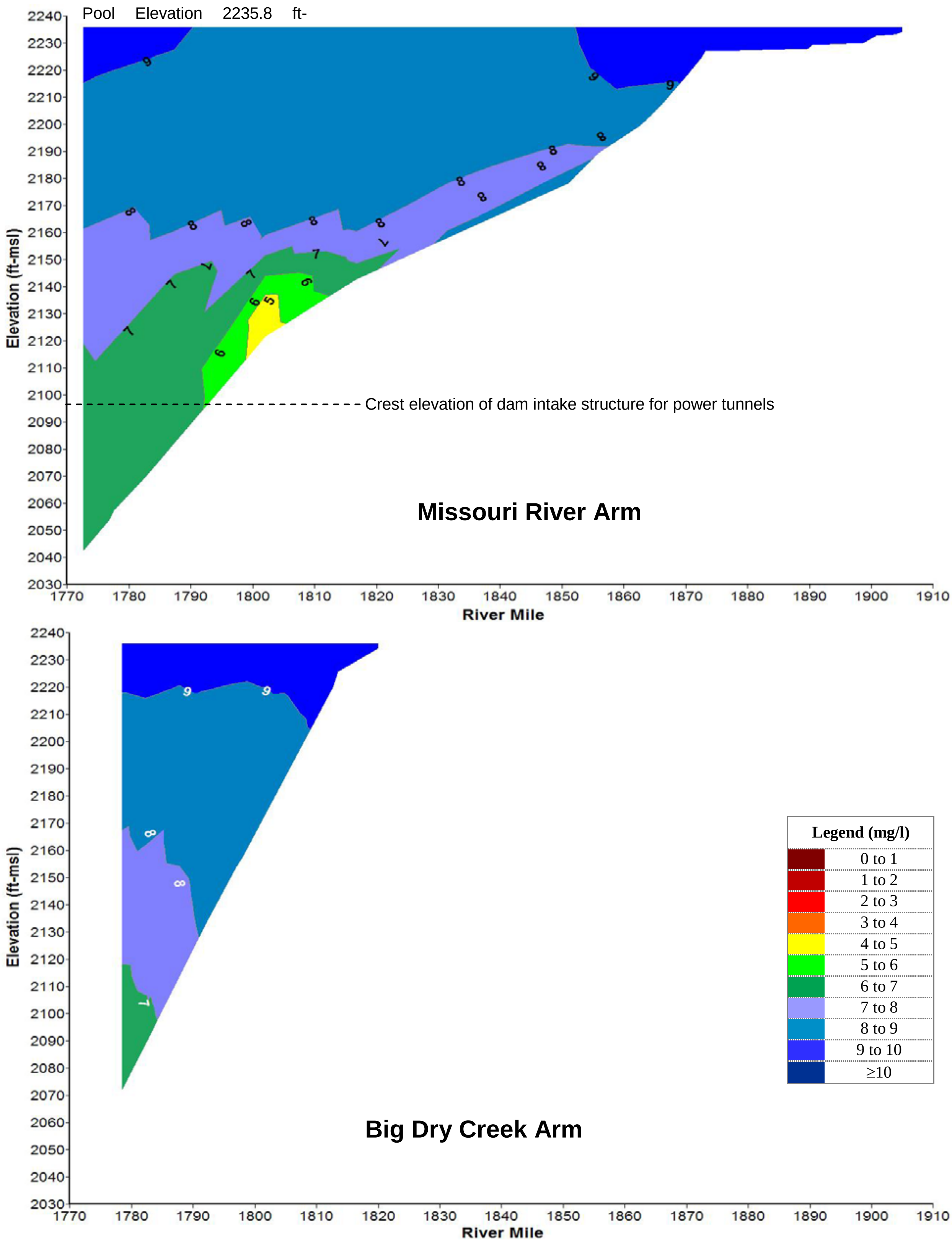

Plate 14. Longitudinal dissolved oxygen (mg/l) contour plot of Fort Peck Lake based on depth-profile dissolved oxygen concentrations monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on September 22, 2010.

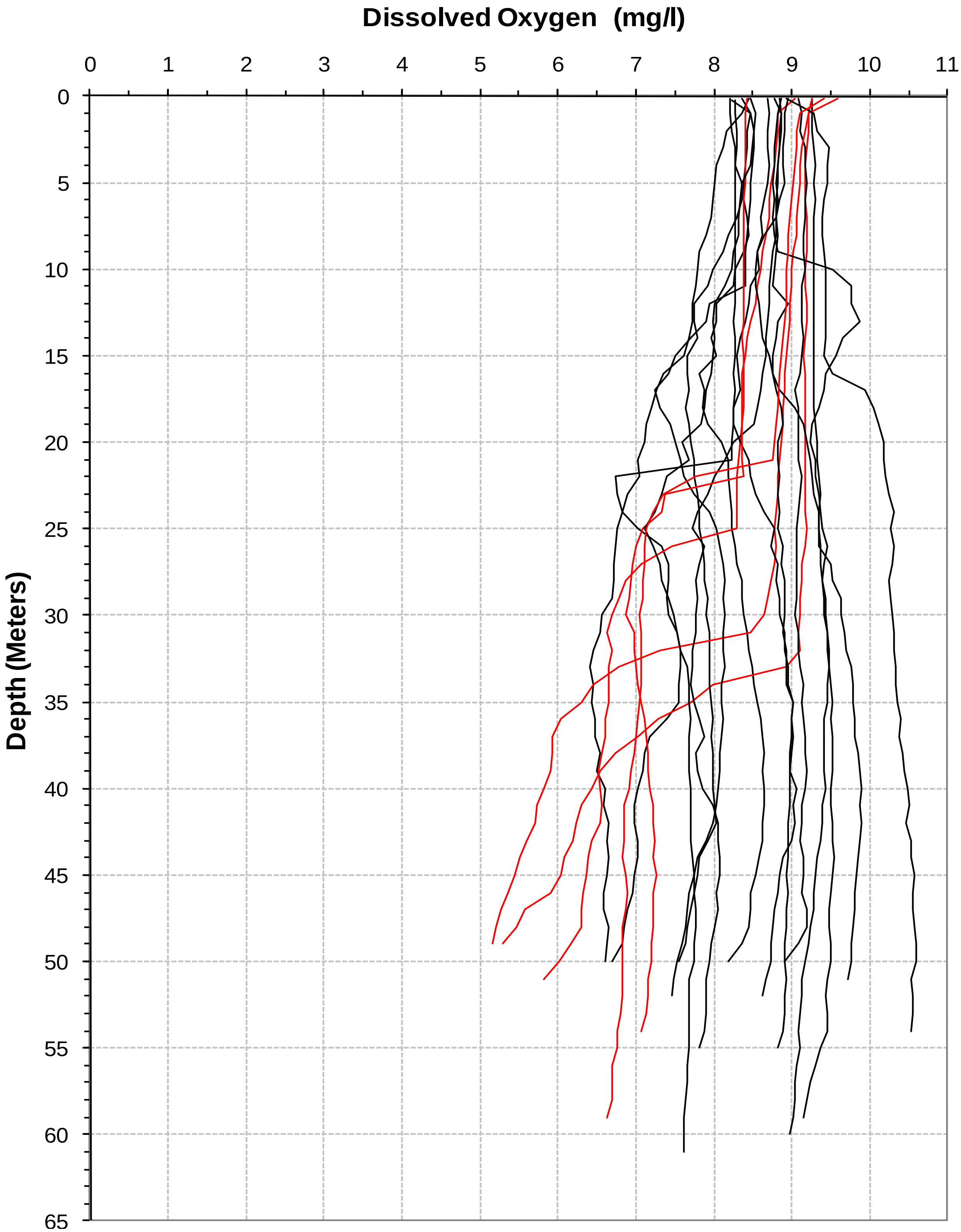

Plate 15. Dissolved oxygen depth profiles for Fort Peck Lake compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., FTPLK1772A) during the summer over the 5-year period of 2006 to 2010.
(Note: Red profile plots were measured in the month of September.)

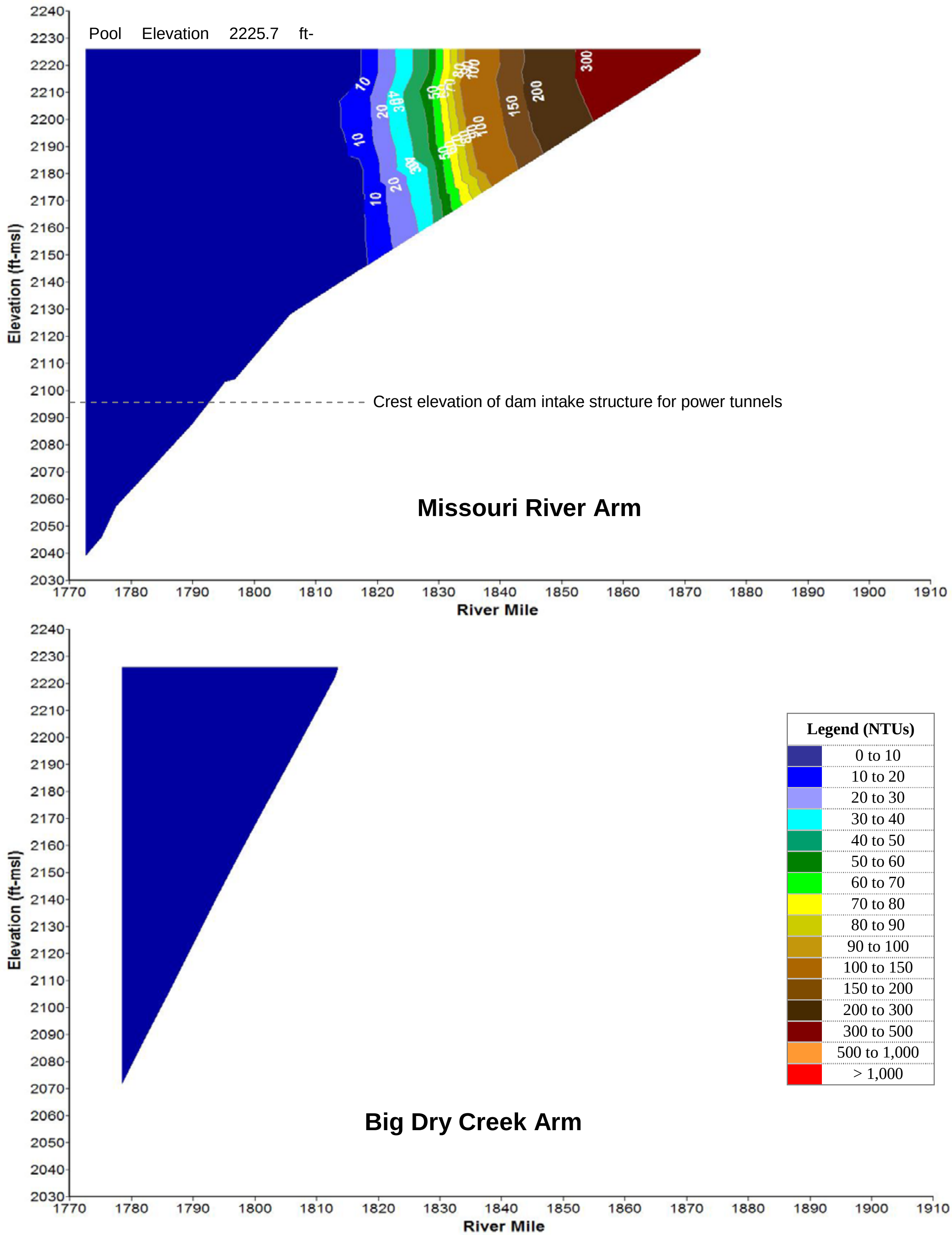

Plate 16. Longitudinal turbidity (NTU) contour plot of Fort Peck Lake based on depth-profile turbidity levels monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on May 19, 2010.

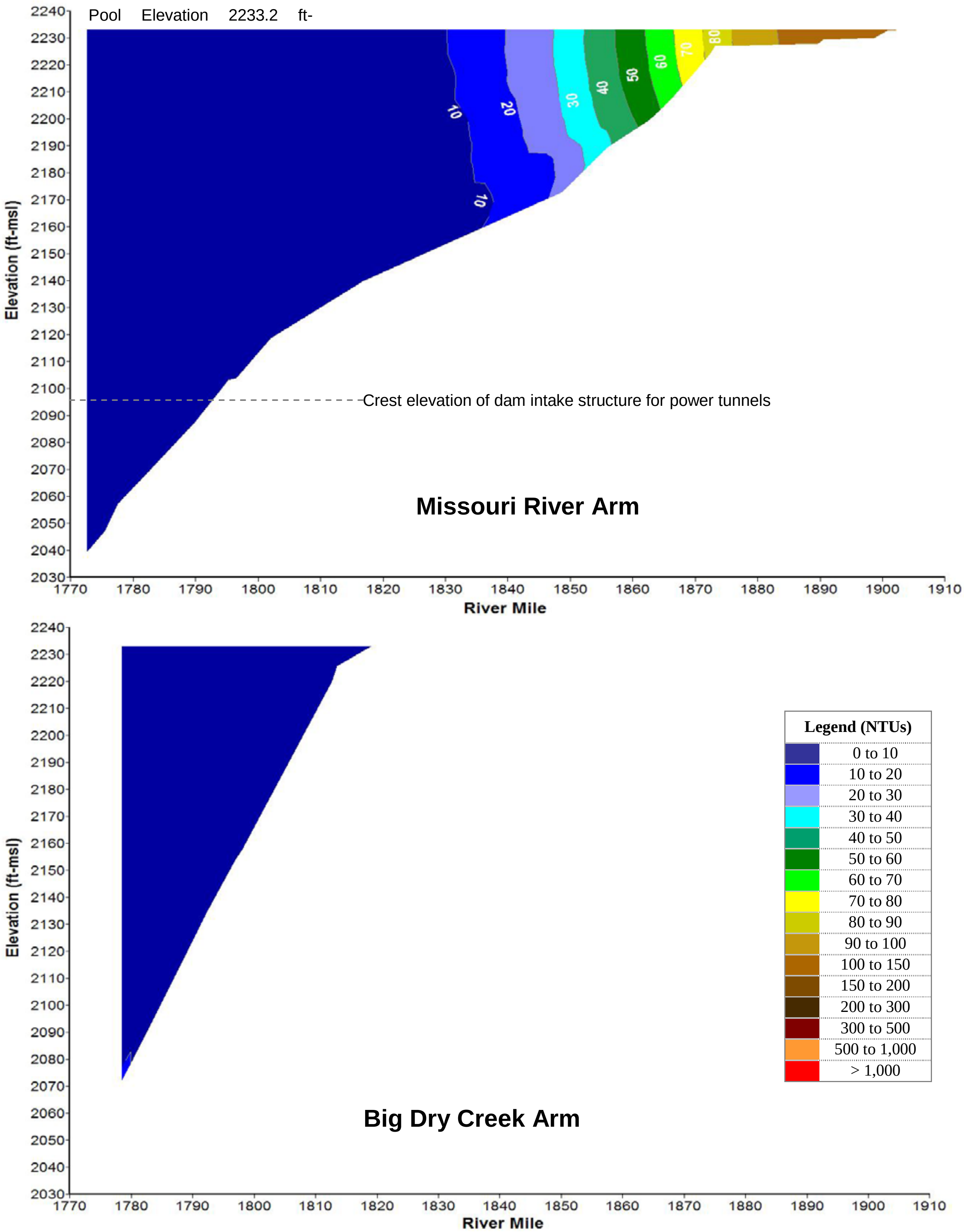

Plate 17. Longitudinal turbidity (NTU) contour plot of Fort Peck Lake based on depth-profile turbidity levels monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on June 30, 2010.

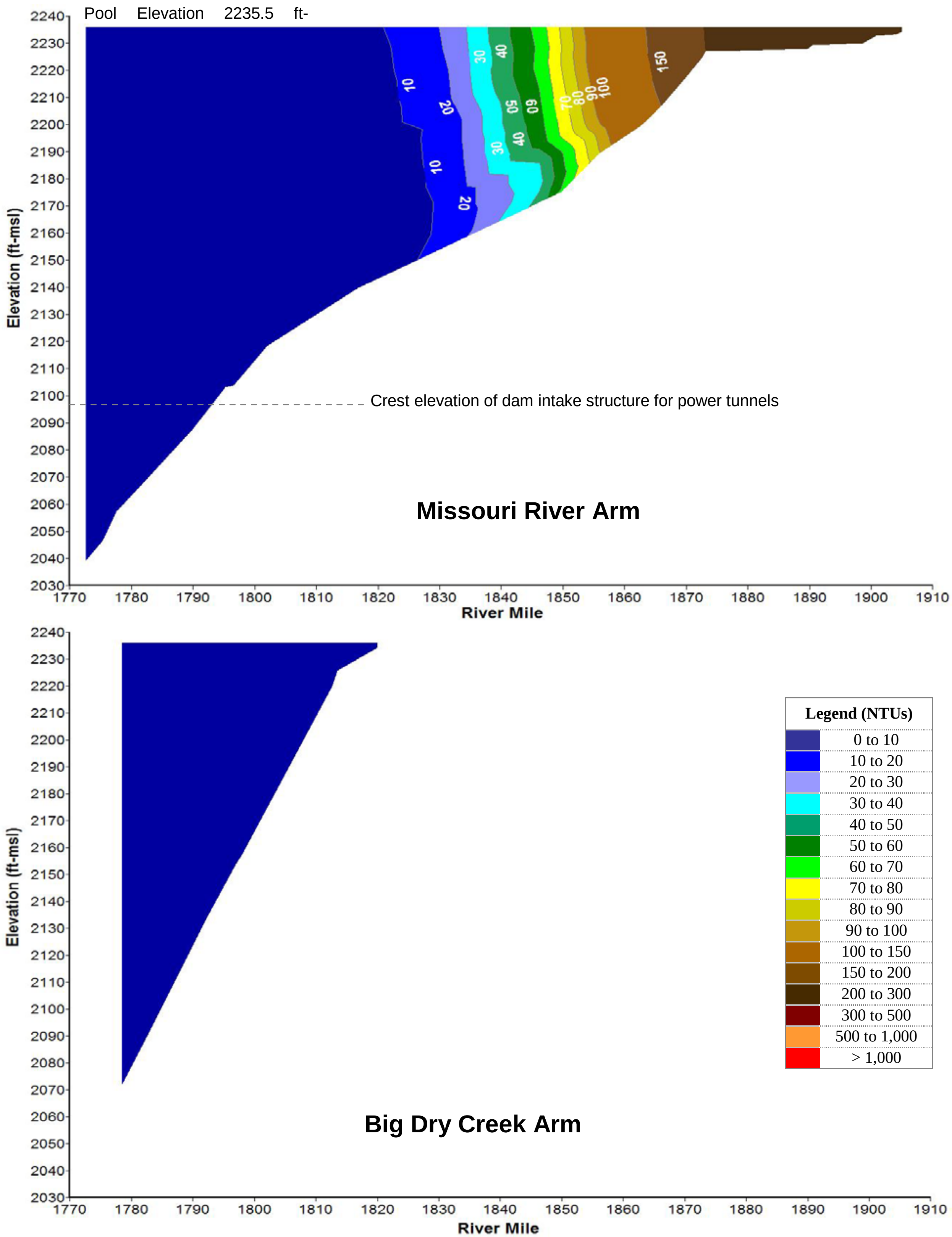

Plate 18. Longitudinal turbidity (NTU) contour plot of Fort Peck Lake based on depth-profile turbidity levels monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on July 21, 2010.

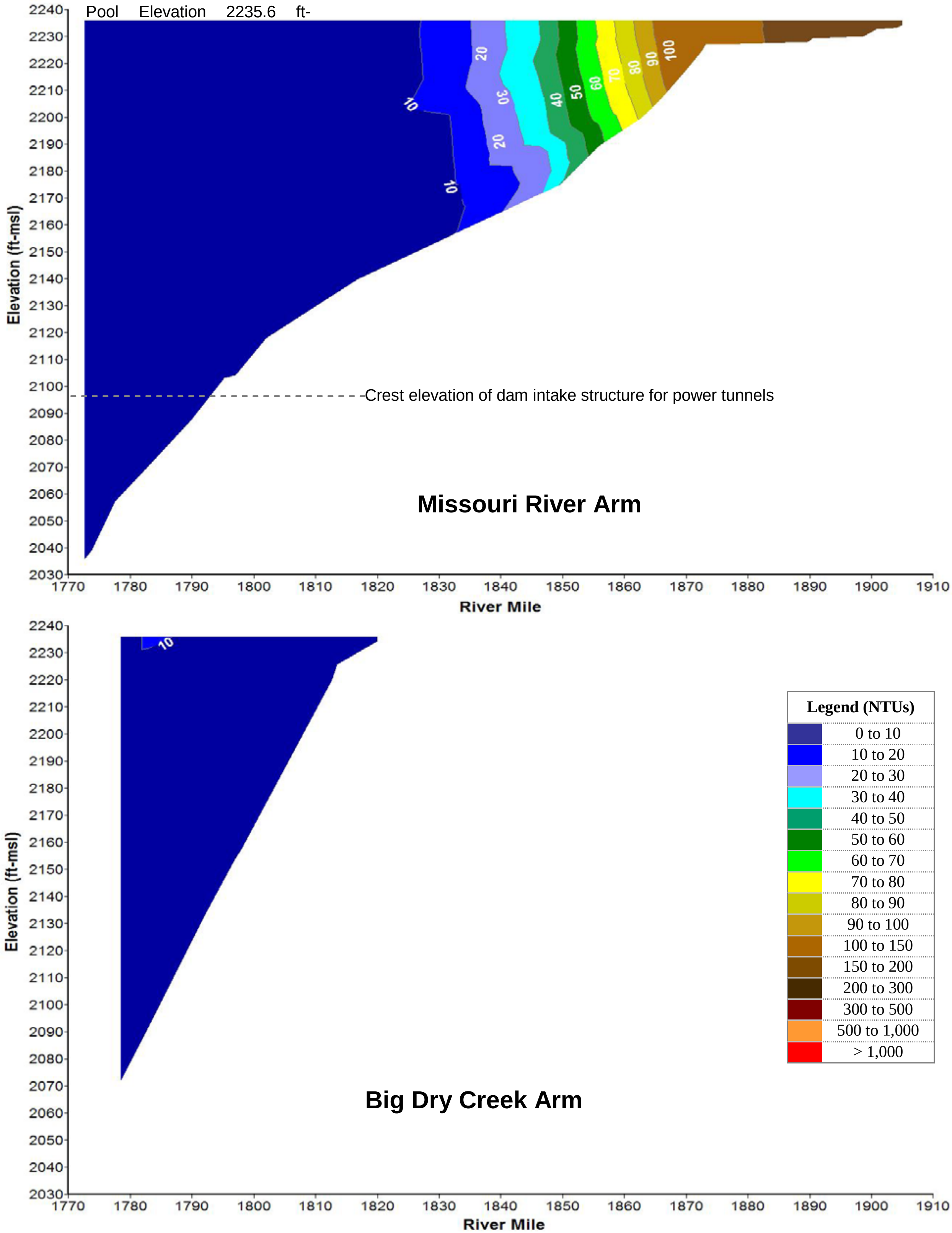

Plate 19. Longitudinal turbidity (NTU) contour plot of Fort Peck Lake based on depth-profile turbidity levels monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on August 24, 2010.

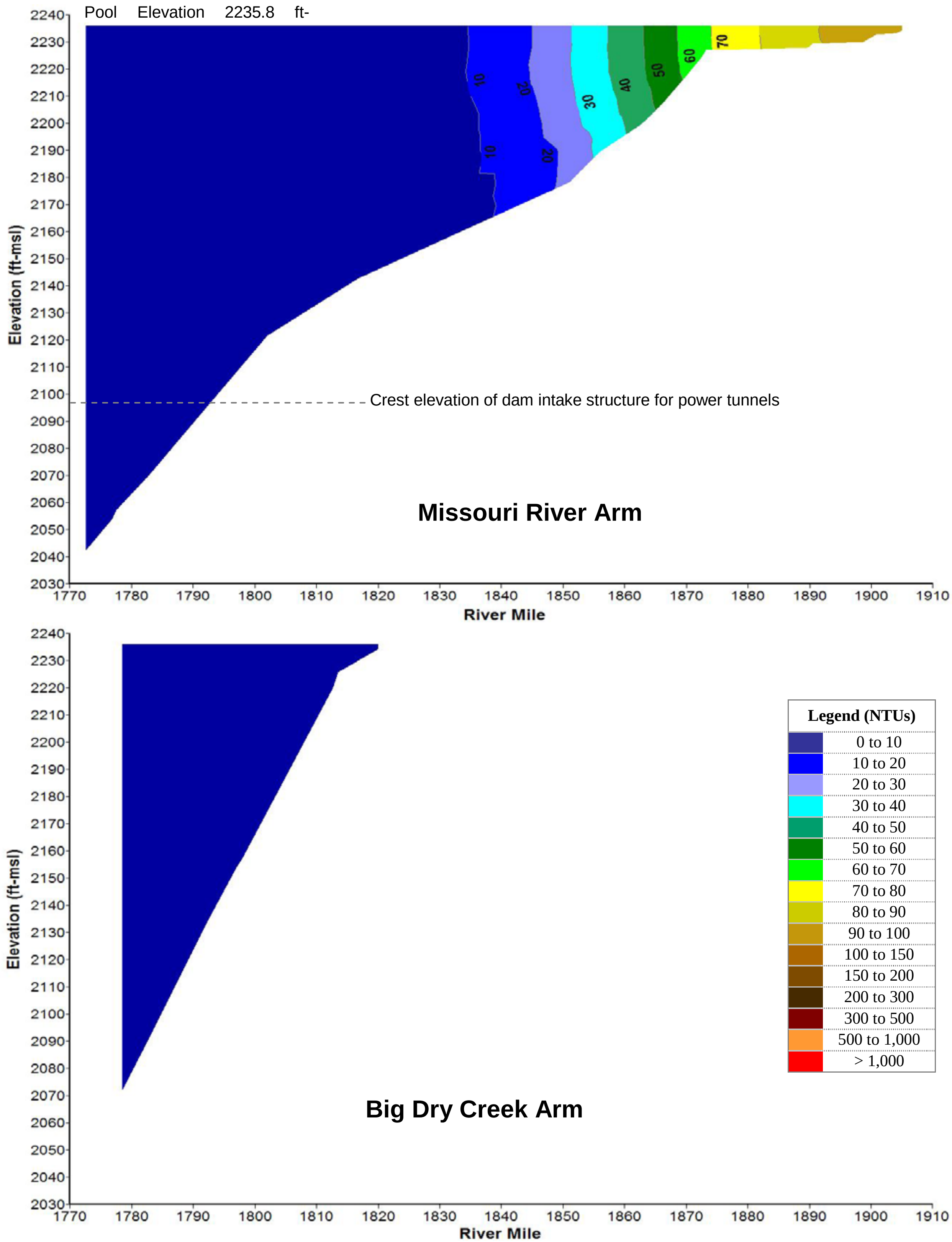

Plate 20. Longitudinal turbidity (NTU) contour plot of Fort Peck Lake based on depth-profile turbidity levels monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on September 22, 2010.

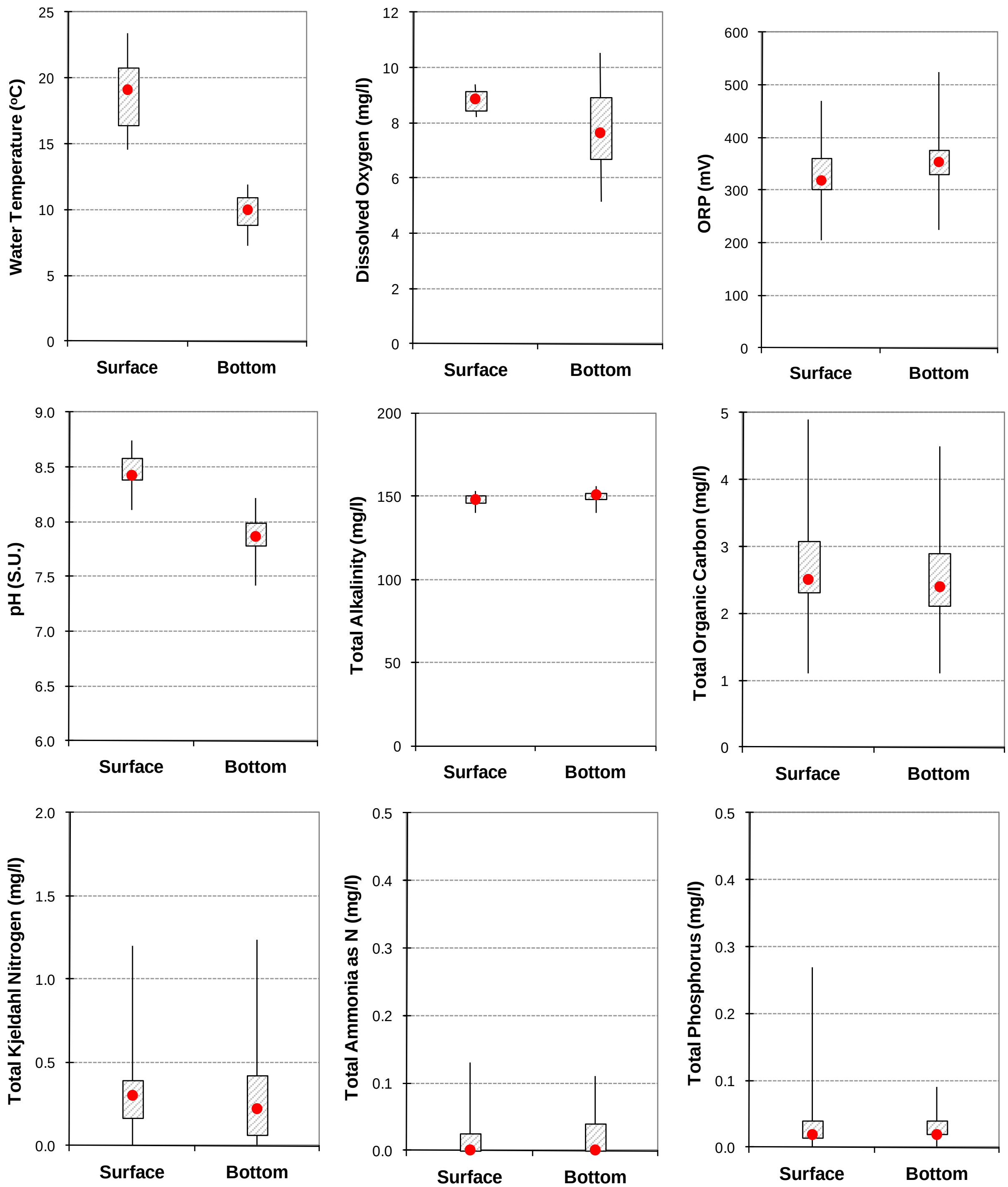

Plate 21. Box plots comparing paired surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus measurements taken in Fort Peck Lake at site FTPLK1772A during the summer months of 2006 through 2010.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 22. Total biovolume, number of genera, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Fort Peck Lake at site FTPLK1772A during the 5-year period 2006 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
May 2006	0.0389	6	0.99	1	0.01	0	-----	0	-----	0	-----	0	-----	1	<0.01
Jun 2006	0.1062	4	0.89	2	0.02	1	<0.01	1	<0.01	1	0.08	0	-----	1	<0.01
Jul 2006	0.0997	8	0.25	3	0.01	1	0.03	1	0.01	3	0.34	2	0.35	1	0.01
Aug 2006	0.1466	6	0.85	3	0.05	0	-----	1	0.03	2	0.07	0	-----	0	-----
Sep 2006	0.1871	4	0.95	2	<0.01	0	-----	1	0.04	2	0.01	0	-----	0	-----
May 2007	1.3514	12	0.99	2	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	0	-----
Jun 2007	0.3419	10	0.89	5	<0.01	1	0.05	1	<0.01	2	<0.01	1	<0.01	0	-----
Jul 2007	0.1643	7	0.06	3	0.01	1	0.09	1	0.03	3	0.60	2	0.21	0	-----
Aug 2007	0.0884	8	0.37	4	0.07	1	0.04	1	0.23	3	0.10	2	0.20	0	-----
Sep 2007	0.0859	6	0.69	7	0.06	1	0.02	2	0.07	5	0.12	2	0.04	0	-----
May 2008	0.3955	3	1.00	3	<0.01	0	-----	1	<0.01	0	-----	0	-----	0	-----
Jun 2008	0.2703	8	0.99	0	-----	2	0.01	0	<0.01	0	-----	0	-----	0	-----
Jul 2008	0.0008	8	0.97	0	-----	1	0.01	1	0.01	2	0.01	2	0.01	0	-----
Aug 2008	0.0380	9	0.15	2	0.24	0	-----	1	0.10	2	0.45	2	0.05	0	-----
Sep 2008	0.1329	5	0.89	3	0.01	0	-----	1	0.03	4	0.03	2	0.04	0	-----
May 2009	0.6892	9	0.96	2	<0.01	1	<0.01	2	0.03	1	0.01	0	-----	1	<0.01
Jun 2009	0.5065	10	0.72	0	-----	2	0.10	1	<0.01	3	0.17	0	-----	1	<0.01
Jul 2009	0.1601	7	0.57	6	0.02	0	-----	1	0.06	5	0.32	1	<0.01	0	-----
Aug 2009	0.6584	8	0.35	3	0.02	1	0.01	2	0.04	4	0.42	1	0.16	1	<0.01
Sep 2009	0.4115	5	0.05	5	0.04	0	-----	2	0.69	1	0.07	0	-----	2	0.16
May 2010	0.1167	6	0.89	3	0.09	0	-----	1	<0.01	1	<0.01	1	0.02	0	-----
Jul 2010	0.3456	8	0.92	8	0.01	1	0.01	2	0.02	5	0.02	1	0.02	0	-----
Sep 2010	0.3831	10	0.88	5	0.02	1	<0.01	2	0.04	2	0.07	1	<0.01	1	<0.01
Mean*	**0.2921**	**7.3**	**0.71**	**3.1**	**0.03**	**0.7**	**0.03**	**1.2**	**0.07**	**2.2**	**0.15**	**0.9**	**0.08**	**0.4**	**0.02**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 23. Total biovolume, number of genera, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Fort Peck Lake at site FTPLK1805DW during the 5-year period 2006 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
Jun 2006	0.4621	8	0.94	7	0.02	2	0.01	1	0.02	0	-----	0	-----	1	<0.01
Jul 2006	0.3394	5	0.19	5	0.10	2	0.03	1	0.22	3	0.43	1	0.03	0	-----
Oct 2006	0.3427	9	0.72	12	0.10	1	0.01	1	0.07	3	0.10	1	<0.01	0	-----
Jun 2007	0.6103	8	0.67	8	0.05	2	0.13	2	0.07	1	<0.01	1	0.08	0	-----
Jul 2007	0.1102	5	0.19	5	0.05	1	<0.01	1	0.22	1	0.08	2	0.46	0	-----
Aug 2007	0.3014	9	0.73	10	0.07	1	<0.01	1	0.02	5	0.16	1	0.02	0	-----
Sep 2007	0.2055	9	0.34	10	0.19	1	0.01	2	0.10	6	0.01	1	0.35	0	-----
May 2008	0.0735	5	0.90	2	0.03	1	0.04	1	0.03	0	-----	0	-----	0	-----
Jun 2008	1.2856	8	0.96	2	0.02	1	<0.01	1	0.01	0	-----	0	-----	0	-----
Aug 2008	0.0295	1	<0.01	4	0.01	1	0.03	1	0.68	6	0.16	1	0.11	0	-----
Sep 2008	0.5780	6	0.90	3	0.03	1	<0.01	1	0.06	3	0.01	1	<0.01	0	-----
Jun 2009	0.2628	8	0.90	5	0.01	1	0.03	1	0.01	3	<0.01	1	0.03	1	0.01
Jul 2009	1.5203	7	0.33	6	0.01	2	0.04	2	0.21	4	0.13	1	0.29	1	<0.01
Aug 2009	0.7528	8	0.32	7	0.05	2	0.14	1	0.03	4	0.31	2	0.15	0	-----
Sep 2009	0.3054	8	0.51	10	0.05	2	0.01	2	0.16	4	0.07	1	0.05	1	0.15
May 2010	0.3054	8	0.73	5	<0.01	1	0.26	0	-----	3	<0.01	1	<0.01	0	-----
Jul 2010	0.1617	3	0.83	11	0.08	2	0.01	2	0.06	3	<0.01	2	0.03	0	-----
Sep 2010	0.2801	8	0.78	10	0.06	0	-----	2	0.12	6	0.01	1	0.02	4	<0.01
Mean*	**0.4527**	**6.8**	**0.61**	**6.8**	**0.05**	**1.3**	**0.04**	**1.3**	**0.12**	**3.1**	**0.10**	**1.0**	**0.11**	**0.4**	**0.03**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 24. Total biovolume, number of genera, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Fort Peck Lake at site FTPLKBDCA02 during the 5-year period 2006 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
Jun 2006	0.0911	8	0.91	3	0.01	0	-----	1	<0.01	2	0.02	0	-----	2	0.06
Jul 2006	0.0732	6	0.11	5	0.07	0	-----	1	0.04	2	0.67	0	-----	2	0.11
Aug 2006	0.0863	5	0.60	4	0.05	0	-----	1	0.14	2	0.21	0	-----	0	-----
Oct 2006	0.1054	4	0.65	5	0.01	0	-----	1	0.12	2	0.21	1	<0.01	0	-----
Jun 2007	0.3619	7	0.72	5	<0.01	1	0.06	1	0.20	1	<0.01	1	0.01	0	----
Jul 2007	0.1973	8	0.06	2	0.01	1	0.14	1	0.06	3	0.48	2	0.26	0	-----
May 2008	0.0541	8	0.96	1	<0.01	1	0.03	1	0.01	0	-----	0	-----	0	-----
Jun 2008	0.3597	8	1.00	2	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	0	-----
Jul 2008	0.0003	2	0.91	3	0.01	1	<0.01	1	0.01	2	0.07	1	0.01	0	-----
Aug 2008	0.0224	2	0.02	2	0.05	0	-----	1	0.51	3	0.41	1	0.01	0	-----
Sep 2008	0.1225	4	0.82	1	<0.01	0	-----	1	0.11	0	-----	1	0.07	0	-----
May 2009	1.5094	8	0.98	1	<0.01	1	<0.01	1	0.02	1	<0.01	0	-----	0	-----
Jun 2009	0.0855	8	0.77	2	<0.01	1	0.19	1	0.01	2	0.02	0	-----	0	-----
Jul 2009	0.0312	6	0.81	4	0.01	0	-----	1	0.05	5	0.08	1	0.05	0	-----
Aug 2009	0.1550	7	0.19	4	0.05	1	0.02	1	0.27	3	0.45	1	0.01	0	-----
Sep 2009	0.1484	8	0.22	6	0.13	0	-----	1	0.53	0	-----	1	0.01	2	0.11
May 2010	0.2040	9	0.94	3	0.06	0	-----	0	-----	1	<0.01	0	-----	0	-----
Jul 2010	0.2459	5	0.94	2	<0.01	0	-----	1	<0.01	3	0.02	1	0.03	1	<0.01
Sep 2010	0.1191	7	0.61	5	0.02	1	<0.01	2	0.27	3	0.09	0	-----	2	<0.01
Mean*	**0.2091**	**6.3**	**0.64**	**3.2**	**0.03**	**0.5**	**0.05**	**1.0**	**0.13**	**1.8**	**0.18**	**0.6**	**0.05**	**0.5**	**0.06**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 25. Estimated biomass, number of species, and percent composition (based on biomass) by taxonomic grouping for zooplankton tow samples collected in Fort Peck Lake at Sites FTPLK1772A, FTPLK1805DW, and FTPLKBDCA02 during 2010.

Date	Estimated Biomass (µg/L dry wt.)	Cladocerans		Copepods		Rotifers	
		No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.
Site FTPLK1772A – Near Dam							
May 2010	7.48	1	0.15	3	0.67	8	0.19
July 2010	14.93	2	0.22	2	0.77	9	0.01
Sept 2010	8.34	4	0.38	7	0.62	8	<0.01
Mean	**10.25**	**2.3**	**0.25**	**4.0**	**0.69**	**8.3**	**0.07**
Site FTPLK1805DW – Hell Creek							
May 2010	6.29	2	0.25	3	0.67	7	0.08
July 2010	37.81	2	0.59	4	0.41	4	<0.01
Sept 2010	30.33	5	0.62	3	0.36	8	0.01
Mean	**24.81**	**3.0**	**0.49**	**3.3**	**0.48**	**6.3**	**0.03**
Site FTPLKBDCA02 – Rock Creek area of the Big Dry Creek Arm							
May 2010	6.44	1	0.01	2	0.94	7	0.05
July 2010	55.76	3	0.62	5	0.38	5	<0.01
Sept 2010	11.86	3	0.55	5	0.44	5	0.01
Mean	**24.69**	**2.3**	**0.39**	**4.0**	**0.59**	**5.7**	**0.02**

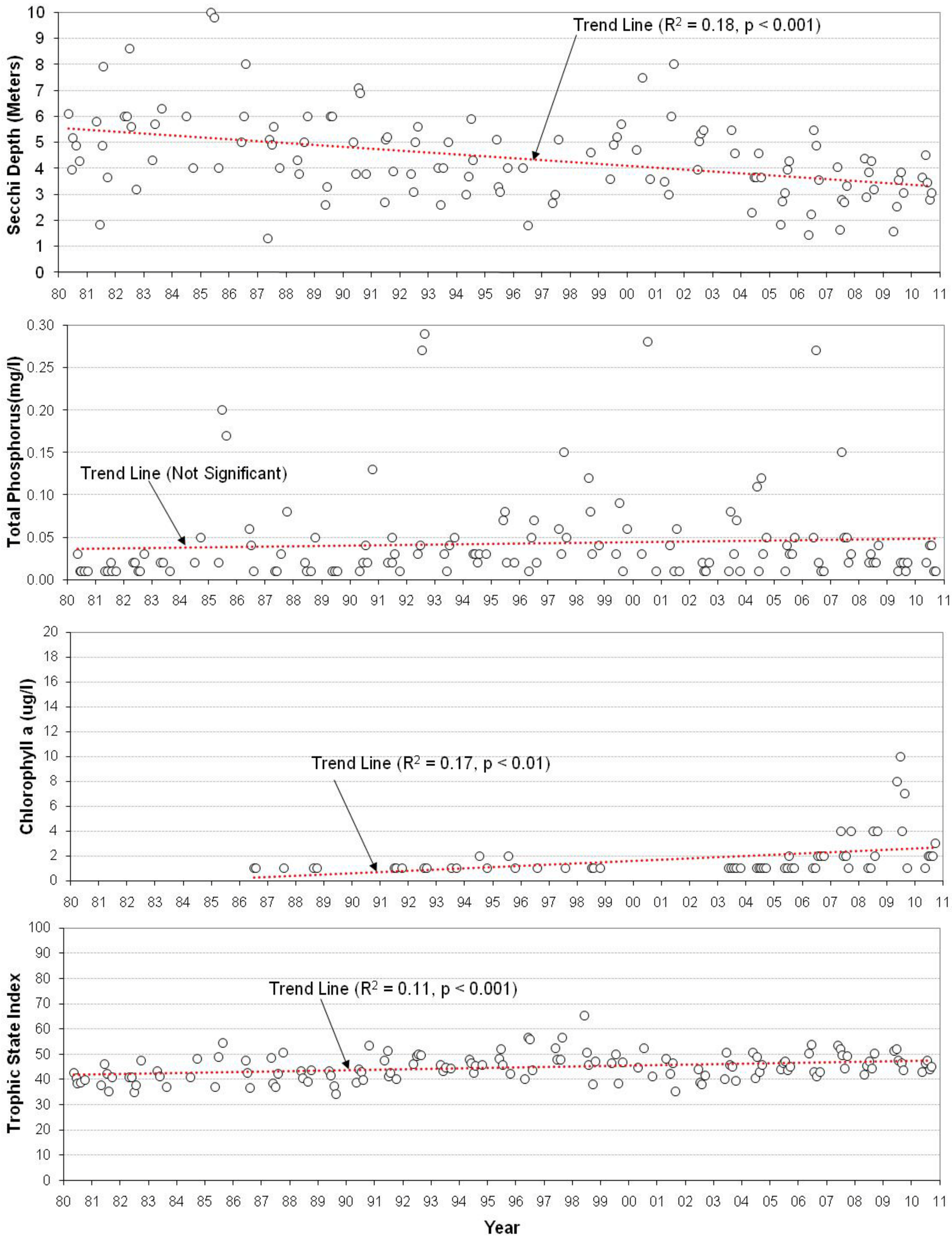

Plate 26. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Fort Peck Lake at site FTPLK1772A over the 31-year period of 1980 through 2010.

Plate 27. Summary of monthly (April through September) near-surface water quality conditions monitored in the Missouri River near Landusky, Montana at monitoring site FTPNFMORR1 during the 5-year period 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	27	9,090	7,830	3,978	25,300	-----	-----	-----
Water Temperature (°C)	0.1	27	17.4	18.1	7.1	26.4	26.7(1,2)	0	0%
Dissolved Oxygen (mg/l)	0.1	27	809	8.7	7.0	11.2	5.0(1,3)	0	0%
Dissolved Oxygen (% Sat.)	0.1	27	95.6	96.0	81.2	103.6	-----	-----	-----
pH (S.U.)	0.1	27	805	806	8.0	9.0	6.5(1,3), 9.0(1,2)	0, 1	0%, 4%
Specific Conductance (umhos/cm)	1	27	460	443	376	696	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	27	318	311	199	436	-----	-----	-----
Turbidity (NTU)	1	27	322	48	1	3,000	-----	-----	-----
Alkalinity, Total (mg/l)	7	27	143	144	120	175	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	26	3.0	2.9	1.1	4.4	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	27	20	12	4	171	-----	-----	-----
Chloride, Dissolved (mg/l)	1	21	8	9	6	11	-----	-----	-----
Chlorophyll a (ug/l)	1	6	9	7	2	23	-----	-----	-----
Color (APHA)	1	6	8	7	5	13	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	27	299	286	216	509	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	27	-----	n.d.	n.d.	0.46	2.6 (1,2,4), 0.71(1,4,5)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	27	1.0	0.6	n.d.	5.9	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	27	-----	n.d.	n.d.	0.30	-----	-----	-----
Nitrogen, Total (mg/l)	0.1	27	1.0	0.7	n.d.	6.1	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	27	-----	0.02	n.d.	0.15	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	27	0.39	0.11	0.03	4.70	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	27	-----	n.d.	n.d.	0.09	-----	-----	-----
Sulfate (mg/l)	1	27	90	79	56	229	-----	-----	-----
Suspended Solids, Total (mg/l)	4	27	525	92	16	7,437	-----	-----	-----
Suspended Sediment, Total (mg/l)	4	6(D)	275	175	n.d.	848			

n.d. = Not detected. b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for B-3 classified waters.
- (2) Daily maximum criterion (monitoring results directly comparable to criterion).
- (3) Daily minimum criterion (monitoring results directly comparable to criterion).
- (4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (5) 30-day average criterion (monitoring results not directly comparable to criterion).

(D) Suspended sediment analyses are for samples collected only in 2010.

Plate 28. Summary of annual metals and pesticide levels monitored in the Missouri River near Landusky, Montana at monitoring site FTPNFMORR1 during the 5-year period 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	4	----	n.d.	n.d.	25	750(1), 87(2)	0	0%
Aluminum, Total (ug/l)	25	4	2,394	1,440	800	5,895	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	4	0.5	0.6	0.1	0.6	-----	-----	-----
Antimony, Total (ug/l)	0.5	4	1.8	0.8	0.5	5.0	5.6(1)	0	0%
Arsenic, Dissolved (ug/l)	1	4	12	12	11	14	-----	-----	-----
Arsenic, Total (ug/l)	1	4	14	14	13	15	340(1), 150(2), 10(3)	0, 0, 4	0%, 0%, 100%
Barium, Dissolved (ug/l)	5	4	57	54	50	70	-----	-----	-----
Barium, Total (ug/l)	5	4	66	70	52	74	2,000(3)	0	0%
Beryllium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Beryllium, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	4(3)	0	0%
Cadmium, Dissolved (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Cadmium, Total (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	3.9(1), 0.42(2), 5(3)	0	0%
Calcium, Dissolved (mg/l)	0.01	4	46	45	41	52	-----	-----	-----
Chromium, Dissolved (ug/l)	10	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Chromium, Total (ug/l)	10	4	-----	n.d.	n.d.	n.d.	2,944(1), 141(2), 100(3)	0	0%
Copper, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Copper, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	25(1), 16(2), 1,300(3)	0	0%
Hardness, Total (mg/l)	0.4	4	184	182	171	202	-----	-----	-----
Iron, Dissolved (ug/l)	40	9(A)	-----	14	n.d.	230	-----	-----	-----
Iron, Total (ug/l)	40	9(A)	23,371	1,563	684	145,000	1,000(2), 300(4)	7, 9	78%, 100%
Lead, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Lead, Total (ug/l)	0.5	4	1.3	1.1	0.6	2.5	175(1), 6.8(2), 15(3)	0	0%
Magnesium, Dissolved (mg/l)	0.01	4	17	17	17	18	-----	-----	-----
Manganese, Dissolved (ug/l)	2	9(A)	-----	5	n.d.	20	-----	-----	-----
Manganese, Total (ug/l)	2	9(A)	251	38	21	1,460	50(4)	4	44%
Mercury, Dissolved (ug/l)	0.05	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Mercury, Total (ug/l)	0.05	4	-----	n.d.	n.d.	n.d.	1.7(1), 0.91(2), 0.05(3)	0	0%
Nickel, Dissolved (ug/l)	10	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Nickel, Total (ug/l)	10	4	-----	n.d.	n.d.	n.d.	779(1), 87(2), 100(3)	0	0%
Selenium, Total (ug/l)	1	4	-----	n.d.	n.d.	1	20(1), 5(2), 50(3)	0	0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Silver, Total (ug/l)	1	4	-----	n.d.	n.d.	n.d.	11(1), 100(3)	0	0%
Sodium, Total (mg/l)	0.01	1	22.4	22.4	22.4	22.4	-----	-----	-----
Thallium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Total (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	0.24(3)	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Zinc, Total (ug/l)	10	4	-----	5	n.d.	70	199(6,7), 2,000(3)	0	0%
Pesticide Scan (ug/l)(D)	0.05(E)	4	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

(A) Results for iron (dissolved and total) and manganese (dissolved and total) include some monthly samples.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Acute criterion for aquatic life.

(2) Chronic criterion for aquatic life.

(3) Human health criterion for surface waters.

(4) Secondary Maximum Contaminant Level based on aesthetic properties.

Note: Some of Montana's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

(E) Detection limits vary by pesticide – 0.05 ug/l is a median detection limit for the pesticides in the pesticide scan.

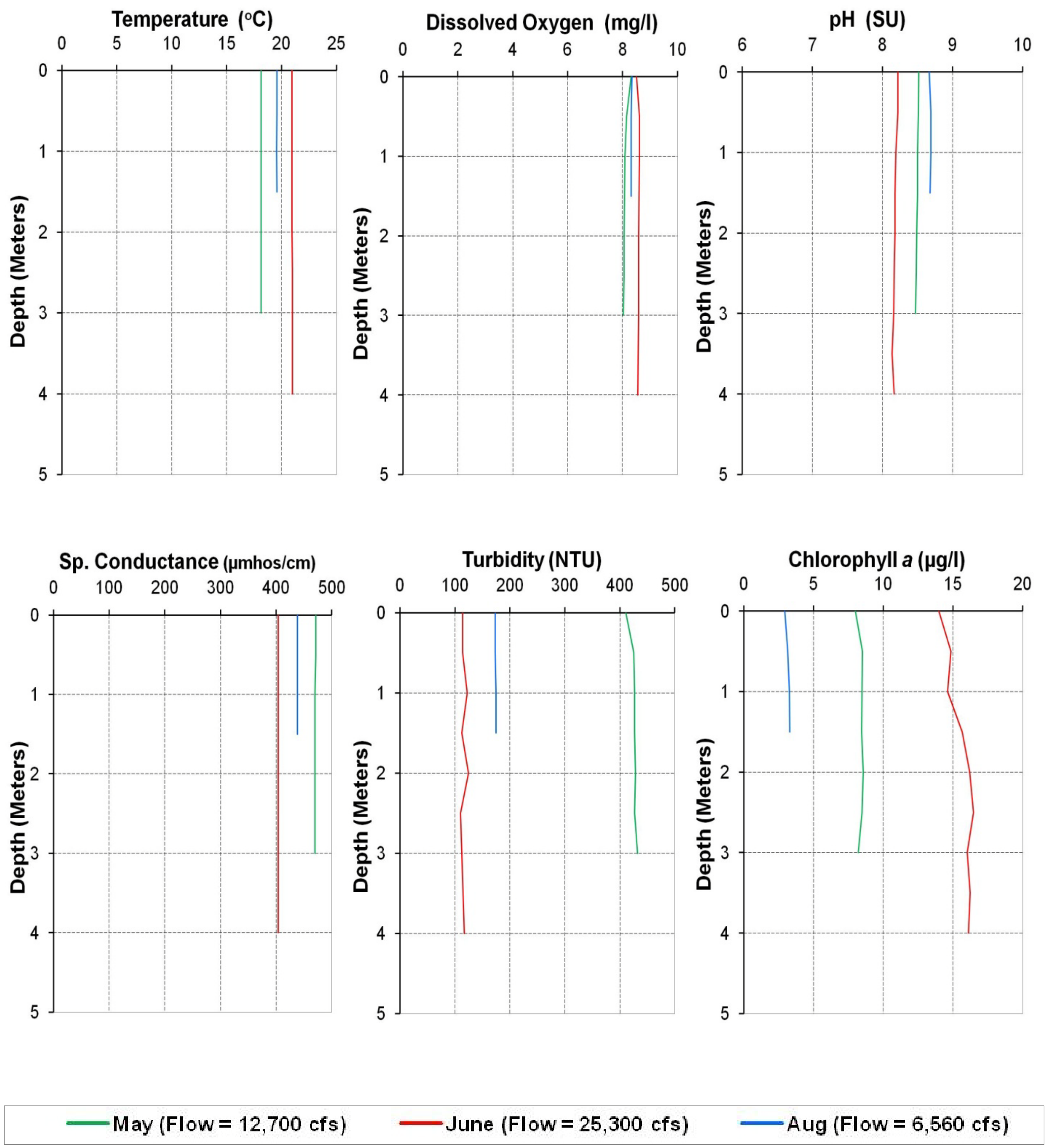

Plate 29. Water temperature, dissolved oxygen, pH, specific conductance, turbidity, and chlorophyll *a* depth profiles for the Missouri River compiled from data collected at the Fort Peck Lake inflow site (i.e., FTPNFMORR1) during 2010.

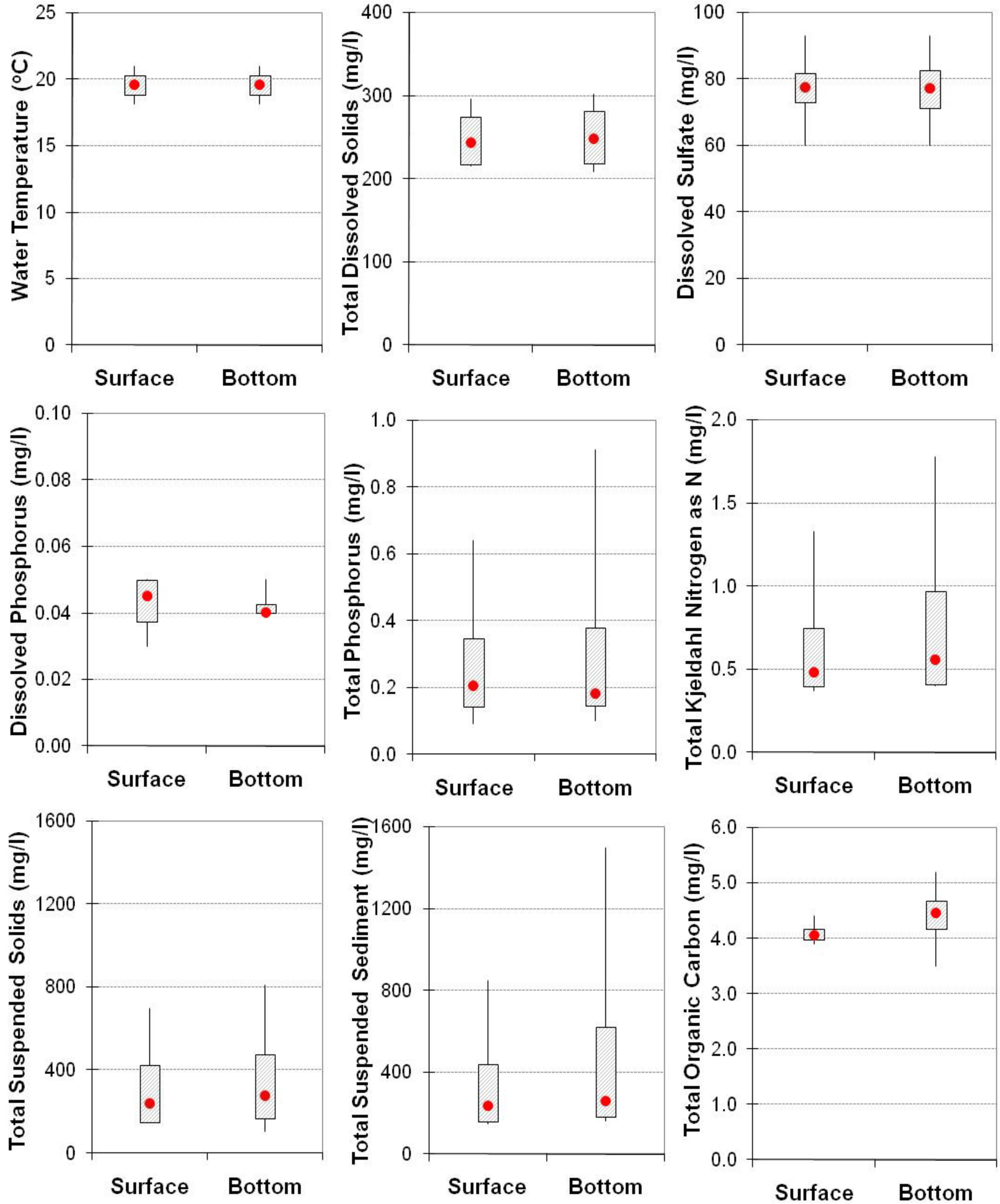

Plate 30. Box plots comparing paired surface and bottom water temperature, total dissolved solids, dissolved sulfate, dissolved phosphorus, total phosphorus, total Kjeldahl nitrogen, total suspended solids, total suspended sediment, and total organic carbon measurements taken in the Missouri River at site FTPNFMORR1 during 2010.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

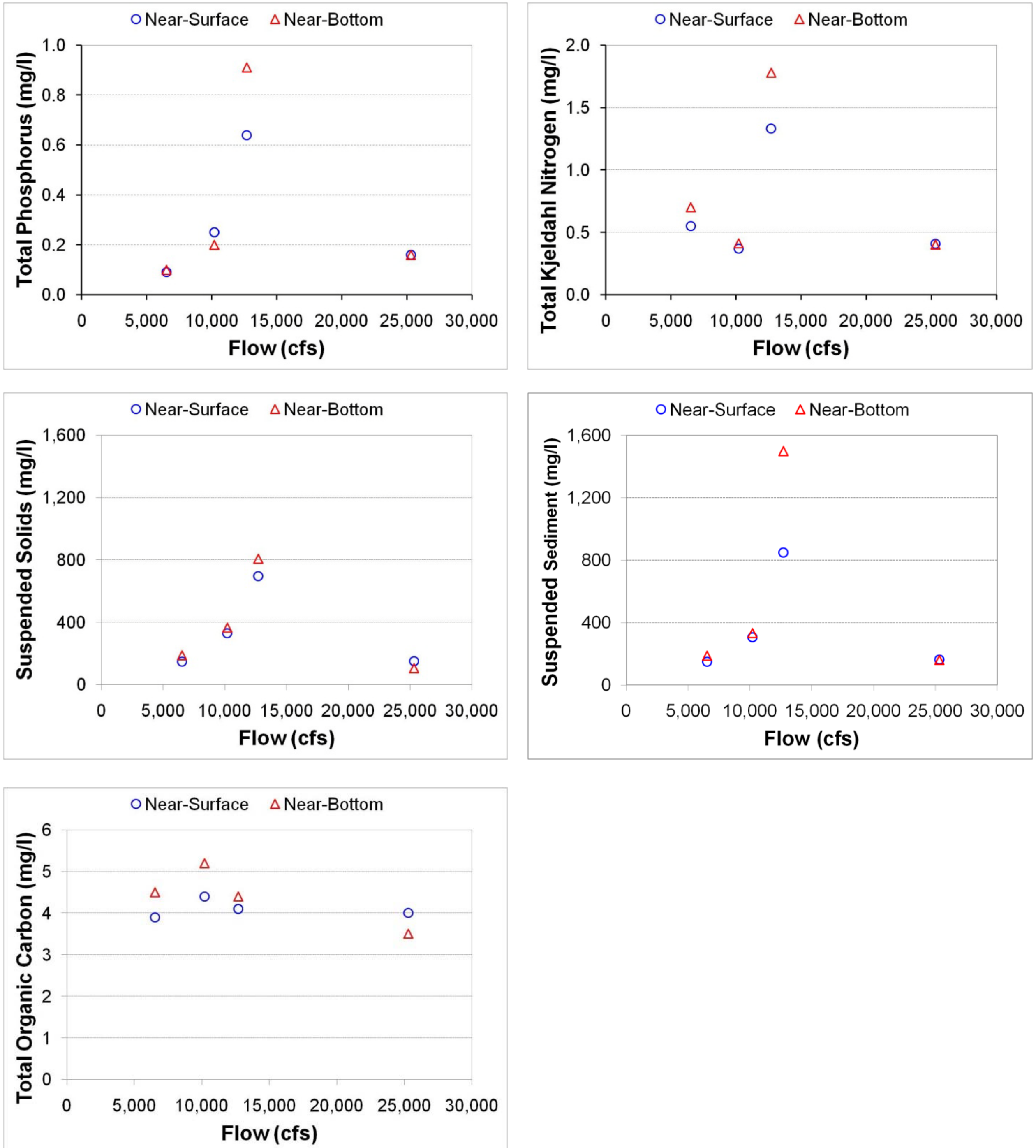

Plate 31. Comparison of flow and measured near-surface and near-bottom concentrations of total phosphorus, total Kjeldahl nitrogen, total suspended sediment, total suspended solids, and total organic carbon in the Missouri River near Landusky, MT (i.e., site FTPNFMORR1).

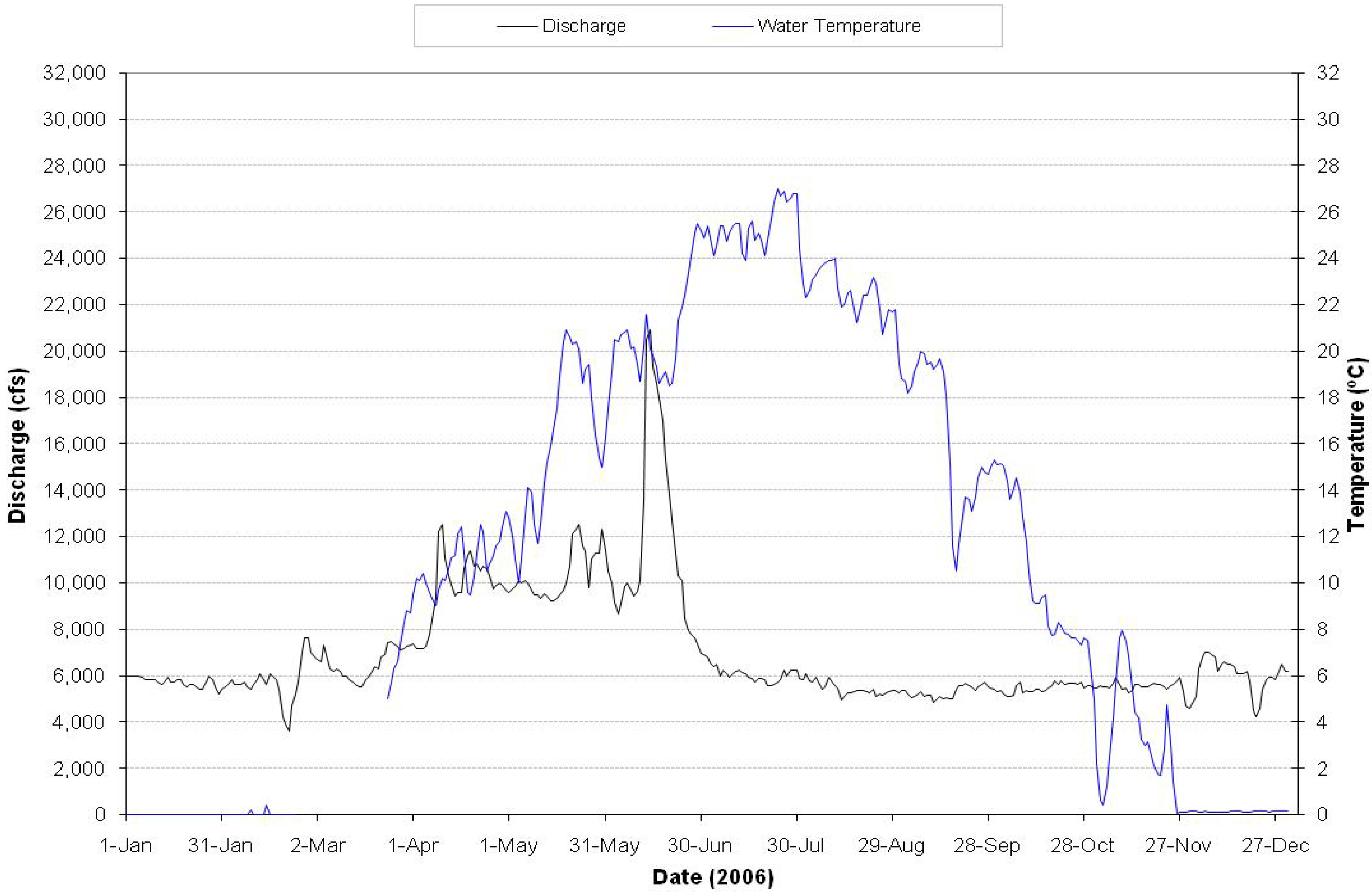

Plate 32. Mean daily discharge and water temperature of the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) for 2006. Means based on measurements recorded at USGS gaging station 06115200.

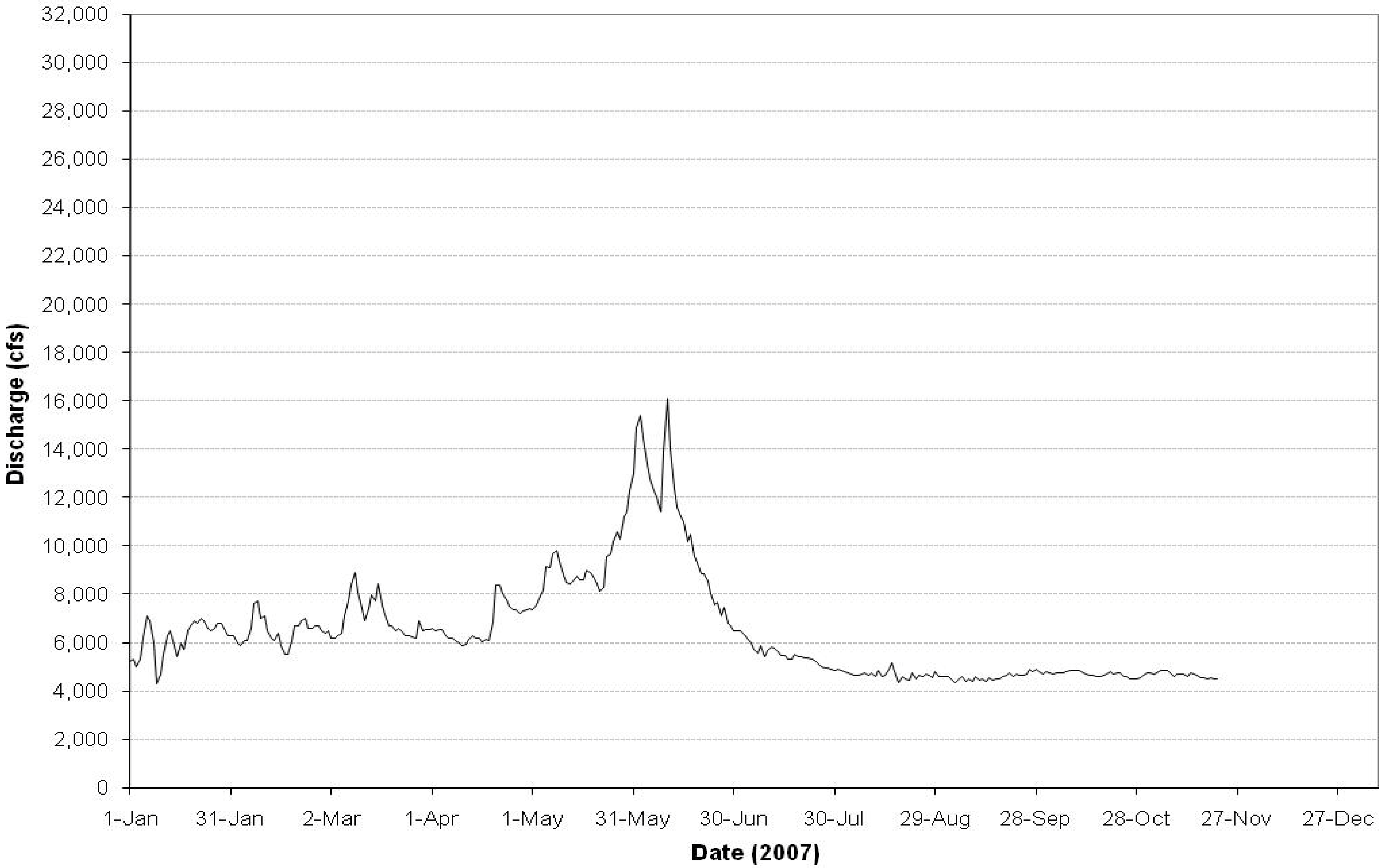

Plate 33. Mean daily discharge of the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) for 2007. Means based on measurements recorded at USGS gaging station 06115200.

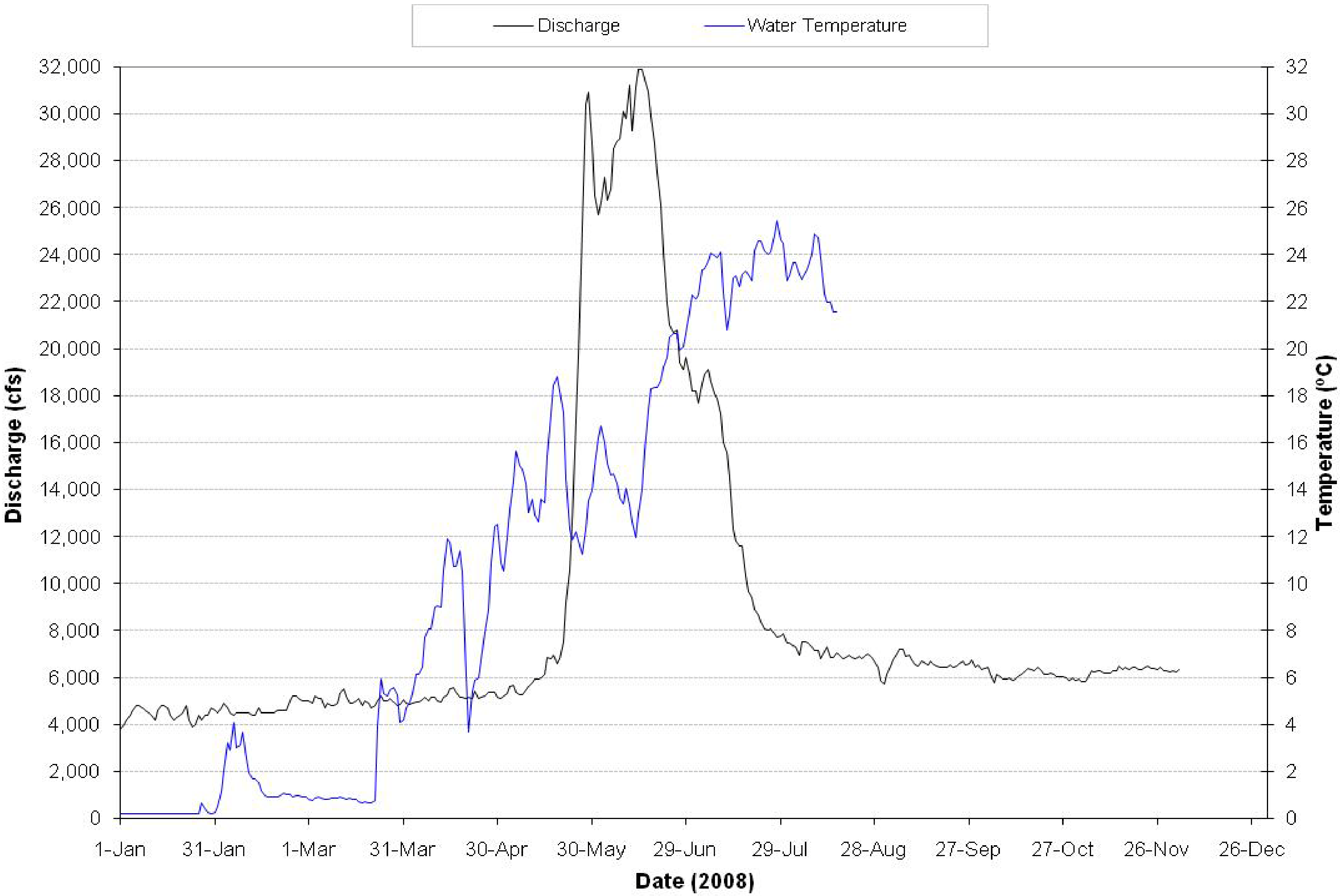

Plate 34. Mean daily discharge and water temperature of the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) for 2008. Means based on measurements recorded at USGS gaging station 06115200.

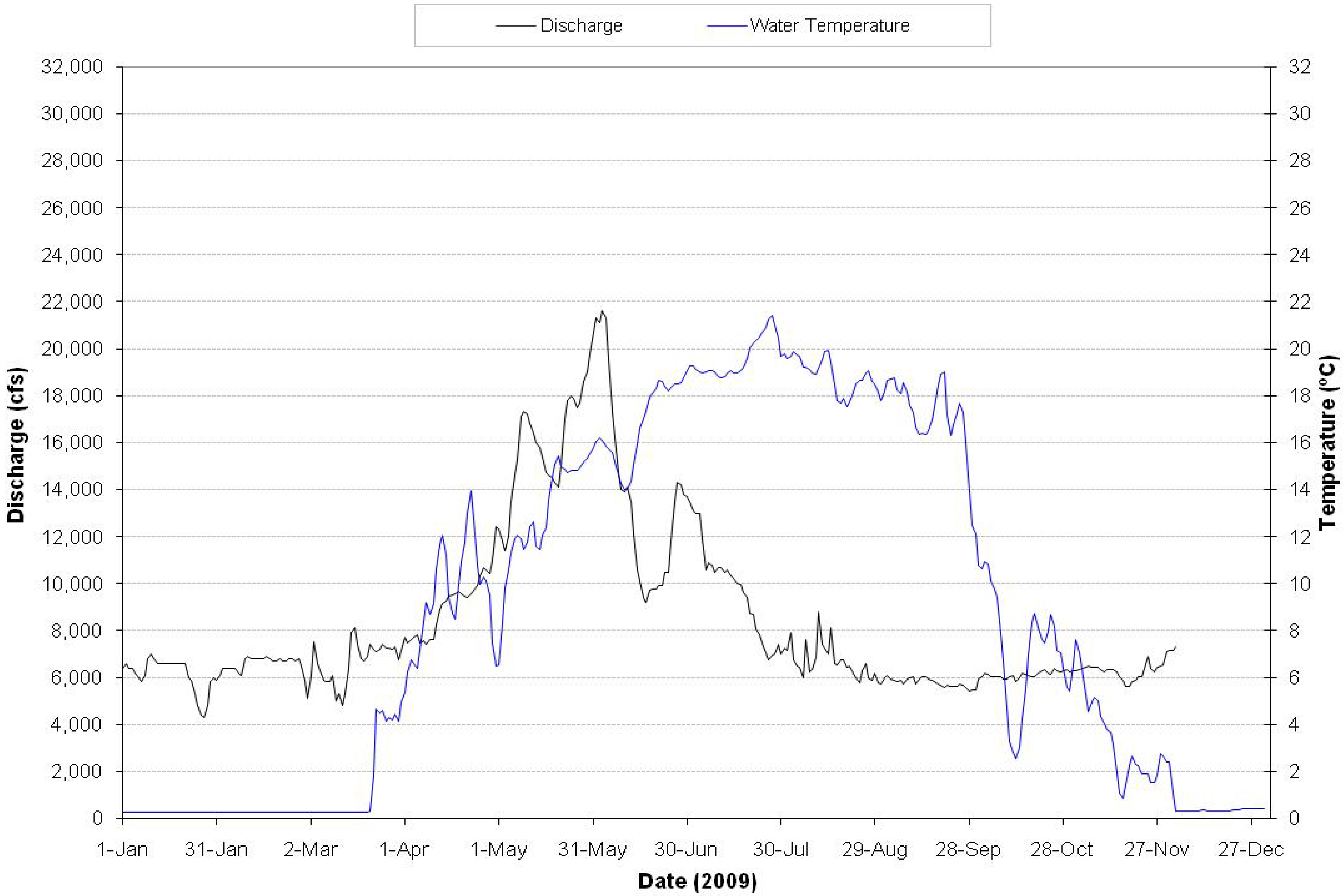

Plate 35. Mean daily discharge and water temperature of the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) for 2009. Means based on measurements recorded at USGS gaging station 06115200.

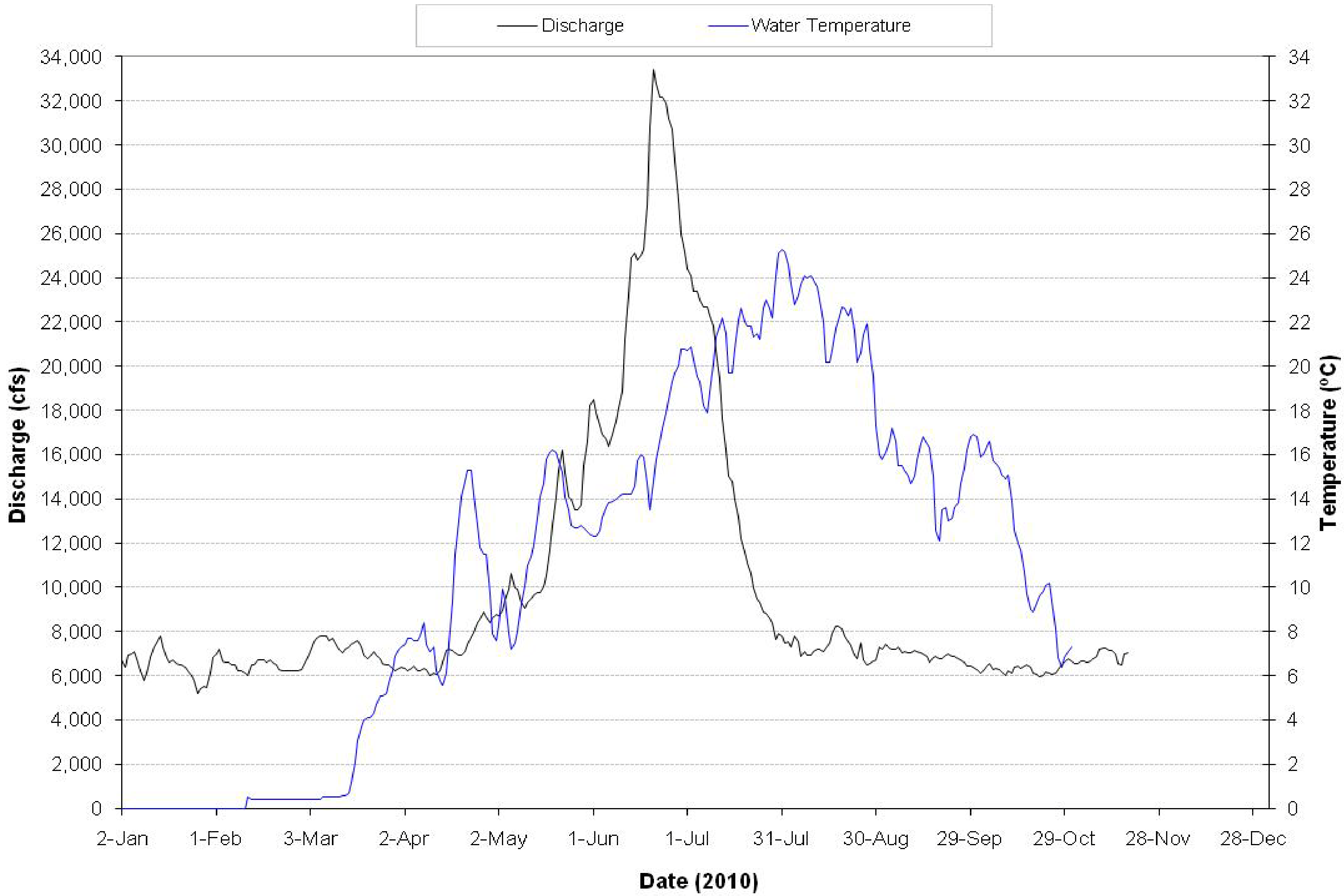

Plate 36. Mean daily discharge and water temperature of the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) for 2010. Means based on measurements recorded at USGS gaging station 06115200.

Plate 37. Summary of monthly water quality conditions monitored from water discharged through Fort Peck Dam (i.e., site FTPPP1) during the 5-year period of January 2006 through December 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Dam Discharge (cfs)	1	48	6,336	5,963	3,423	12,513	-----	-----	-----
Water Temperature (°C)	0.1	45	8.9	9.5	1.4	17.3	19.4(1,4)	0	0%
Dissolved Oxygen (mg/l)	0.1	45	10.4	10.4	6.9	13.8	8.0(1,2,4), 5.0(1,3,4)	5, 0	11%, 0%
Dissolved Oxygen (% Sat.)	0.1	45	92.2	92.4	68.4	107.9	-----	-----	-----
pH (S.U.)	0.1	44	8.3	8.3	7.6	8.7	6.5(1,5), 9.0(1,4)	0	0%
Specific Conductance (umhos/cm)	1	45	544	542	497	704	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	40	355	345	208	511	-----	-----	-----
Turbidity (NTU)	0.1	42	-----	1	n.d.	23	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	154	152	140	174	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	47	2.7	2.7	n.d.	5.6	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	48	8	8	n.d.	41	-----	-----	-----
Chloride, Dissolved (mg/l)	1	39	10	9	7	17	-----	-----	-----
Color, True (APHA)	1								
Dissolved Solids, Total (mg/l)	5	48	367	355	278	534	-----	-----	-----
Hardness, Total (mg/l)	0.4	6	204	207	174	217	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	48	-----	n.d.	n.d.	0.16	3.1 (1,4,6), 1.4 (1,4,7)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	48	-----	0.3	n.d.	1.4	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	48	-----	n.d.	n.d.	0.14	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	46	-----	n.d.	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	48	-----	0.02	n.d.	0.12	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	48	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	48	127	123	107	217	-----	-----	-----
Suspended Solids, Total (mg/l)	4	48	-----	n.d.	n.d.	19	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for B-3 classified waters.
(2) Early life stages.
(3) Non-early life stages.
(4) Daily maximum criterion (monitoring results directly comparable to criterion).
(5) Daily minimum criterion (monitoring results directly comparable to criterion).
(6) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(7) 30-day average criterion (monitoring results not directly comparable to criterion).

Plate 38. Summary of annual metals and pesticide levels monitored from water discharged through Fort Peck Dam (i.e., site FTPPP1) during the 5-year period of January 2006 through December 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean[(B)]	Median	Min.	Max.	State WQS Criteria[(C)]	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	4	-----	n.d.	n.d.	n.d.	750[(1)], 87[(2)]	0	0%
Aluminum, Total (ug/l)	25	4	100	73	50	205	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	4	-----	0.6	n.d.	0.7	-----	-----	-----
Antimony, Total (ug/l)	0.5	4	-----	0.6	n.d.	0.8	5.6[(1)]	0	0%
Arsenic, Dissolved (ug/l)	1	6	-----	4	n.d.	5	-----	-----	-----
Arsenic, Total (ug/l)	1	4	4	4	4	5	340[(1)], 150[(2)], 10[(3)]	0	0%
Barium, Dissolved (ug/l)	5	4	42	42	39	45	-----	-----	-----
Barium, Total (ug/l)	5	4	43	41	39	50	2,000[(3)]	0	0%
Beryllium, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Beryllium, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	4[(3)]	0	0%
Cadmium, Dissolved (ug/l)	0.2	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Cadmium, Total (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	4.5[(1)], 0.46[(2)], 5[(3)]	0	0%
Calcium, Dissolved (mg/l)	0.01	6	51	52	42	55	-----	-----	-----
Chromium, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Chromium, Total (ug/l)	10	4	-----	n.d.	n.d.	n.d.	3,272[(1)], 156[(2)], 100[(3)]	0	0%
Copper, Dissolved (ug/l)	2	6	-----	1	n.d.	4	-----	-----	-----
Copper, Total (ug/l)	2	4	-----	n.d.	n.d.	6	28[(1)], 17[(2)], 1,300[(3)]	0	0%
Hardness, Total (mg/l)	0.4	6	204	207	174	217	-----	-----	-----
Iron, Dissolved (ug/l)	40	15[(A)]	-----	n.d.	n.d.	25	-----	-----	-----
Iron, Total (ug/l)	40	15[(A)]	249	65	n.d.	2,015	1,000[(2)], 300[(4)]	1, 2	7%, 13%
Lead, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	0.6	-----	-----	-----
Lead, Total (ug/l)	0.5	4	-----	1.5	n.d.	2.6	206[(1)], 8.0[(2)], 15[(3)]	0	0%
Magnesium, Dissolved (mg/l)	0.01	6	19	19	17	20	-----	-----	-----
Manganese, Dissolved (ug/l)	2	15[(A)]	-----	n.d.	n.d.	10	-----	-----	-----
Manganese, Total (ug/l)	2	15[(A)]	-----	2	n.d.	31	50[(4)]	0	0%
Mercury, Dissolved (ug/l)	0.05	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Mercury, Total (ug/l)	0.05	6	-----	n.d.	n.d.	n.d.	1.7[(1)], 0.91[(2)], 0.05[(3)]	0	0%
Nickel, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Nickel, Total (ug/l)	10	4	-----	n.d.	n.d.	n.d.	868[(1)], 97[(2)], 100[(3)]	0	0%
Selenium, Total (ug/l)	1	4	-----	n.d.	n.d.	1	20[(1)], 5[(2)], 50[(3)]	0	0%
Silver, Dissolved (ug/l)	1	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Silver, Total (ug/l)	1	4	-----	n.d.	n.d.	n.d.	14[(1)], 100[(3)]	0	0%
Sodium, Dissolved (mg/l)	0.01	1	35	35	35	35	-----	-----	-----
Thallium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Total (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	0.24[(3)]	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	10	-----	-----	-----
Zinc, Total (ug/l)	10	4	-----	5	n.d.	40	222[(6,7)], 2,000[(3)]	0	0%
Pesticide Scan (ug/l)[(D)]	0.05[(E)]	4					-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

(A) Results for iron (dissolved and total) and manganese (dissolved and total) include some monthly samples.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Acute criterion for aquatic life.

(2) Chronic criterion for aquatic life.

(3) Human health criterion for surface waters.

(4) Secondary Maximum Contaminant Level based on aesthetic properties.

Note: Some of Montana's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

(E) Detection limits vary by pesticide – 0.05 ug/l is a median detection limit for the pesticides in the pesticide scan.

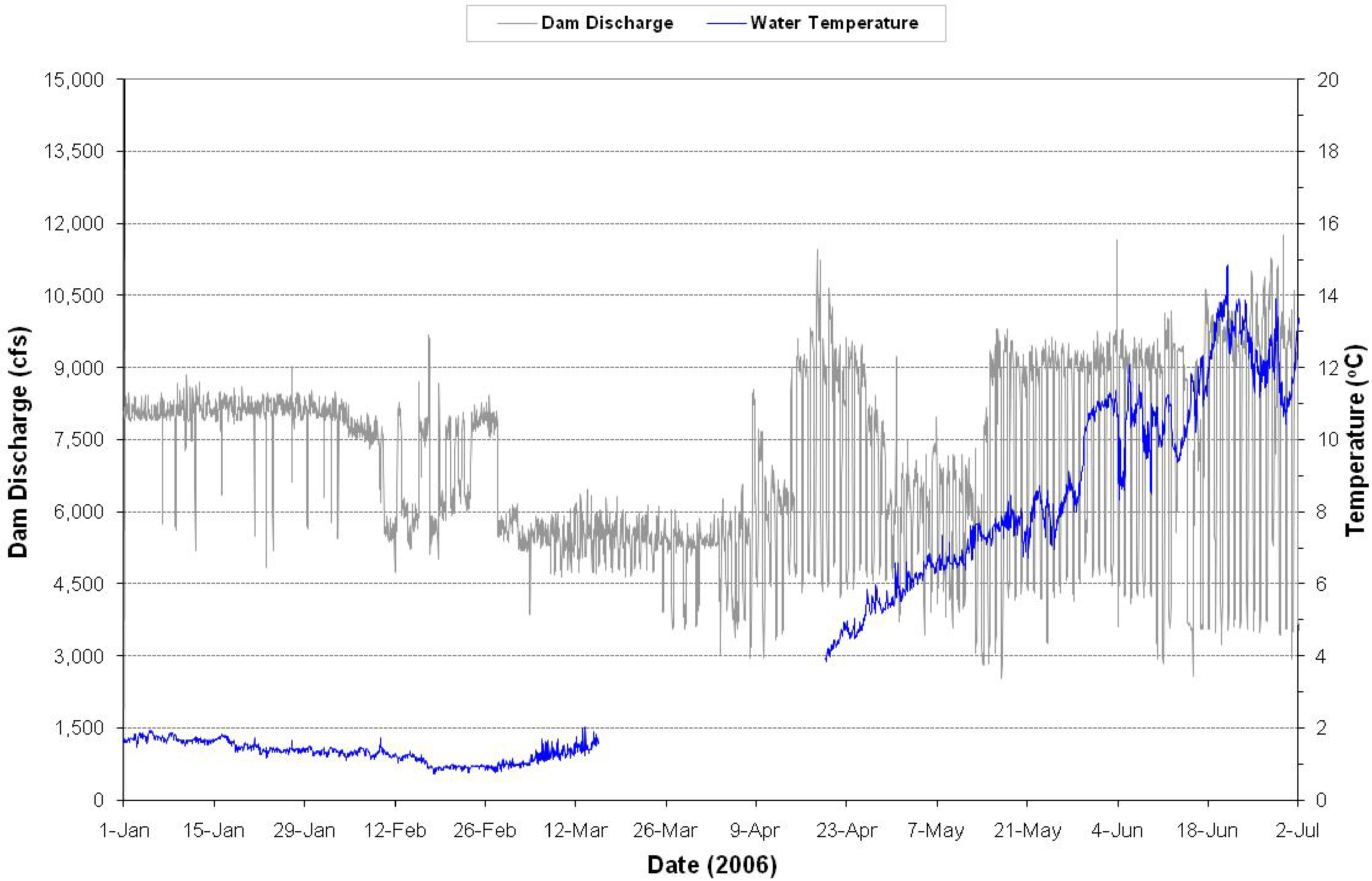

Plate 39. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2006.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

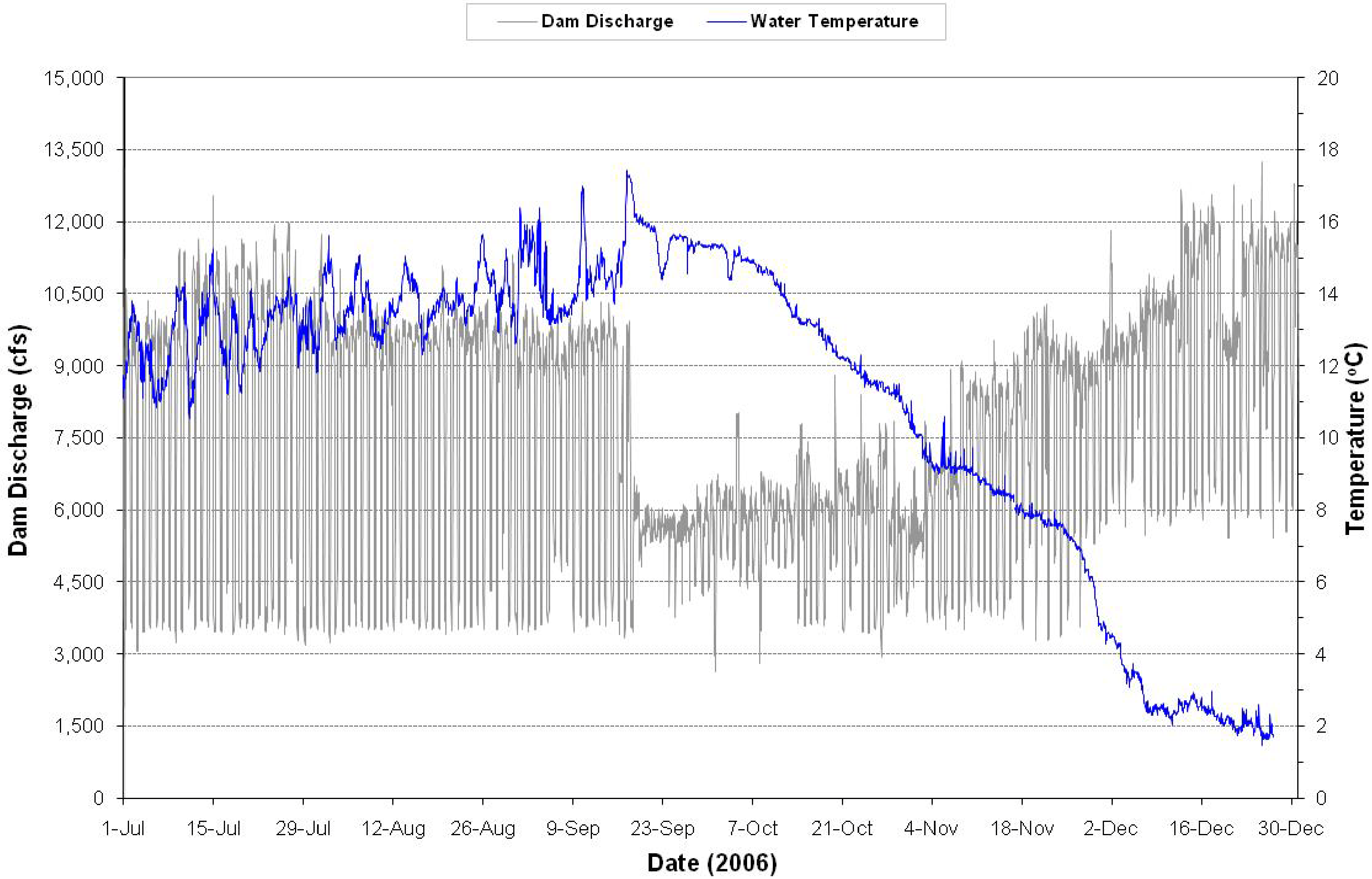

Plate 40. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2006.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

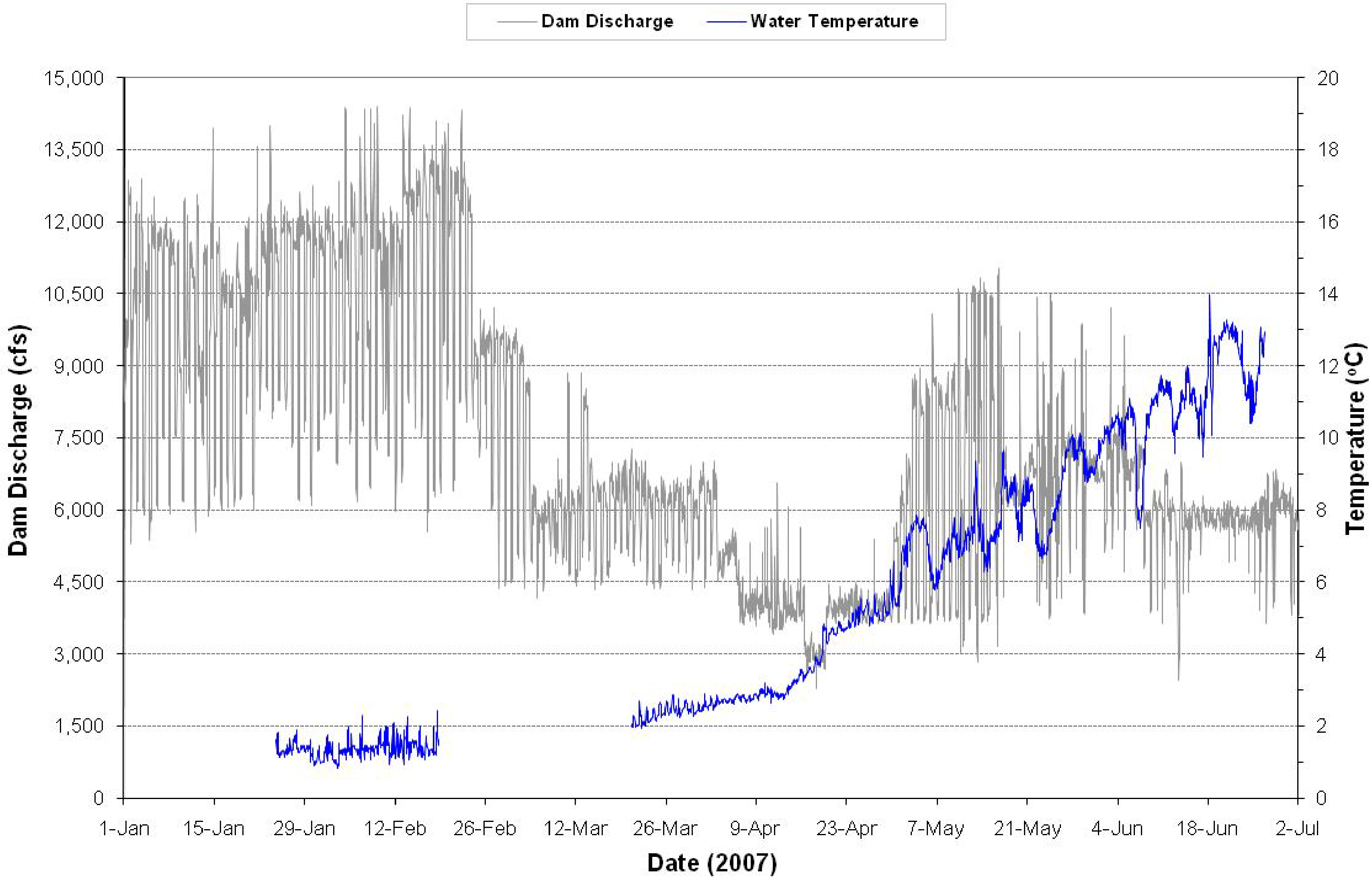

Plate 41. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2007.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

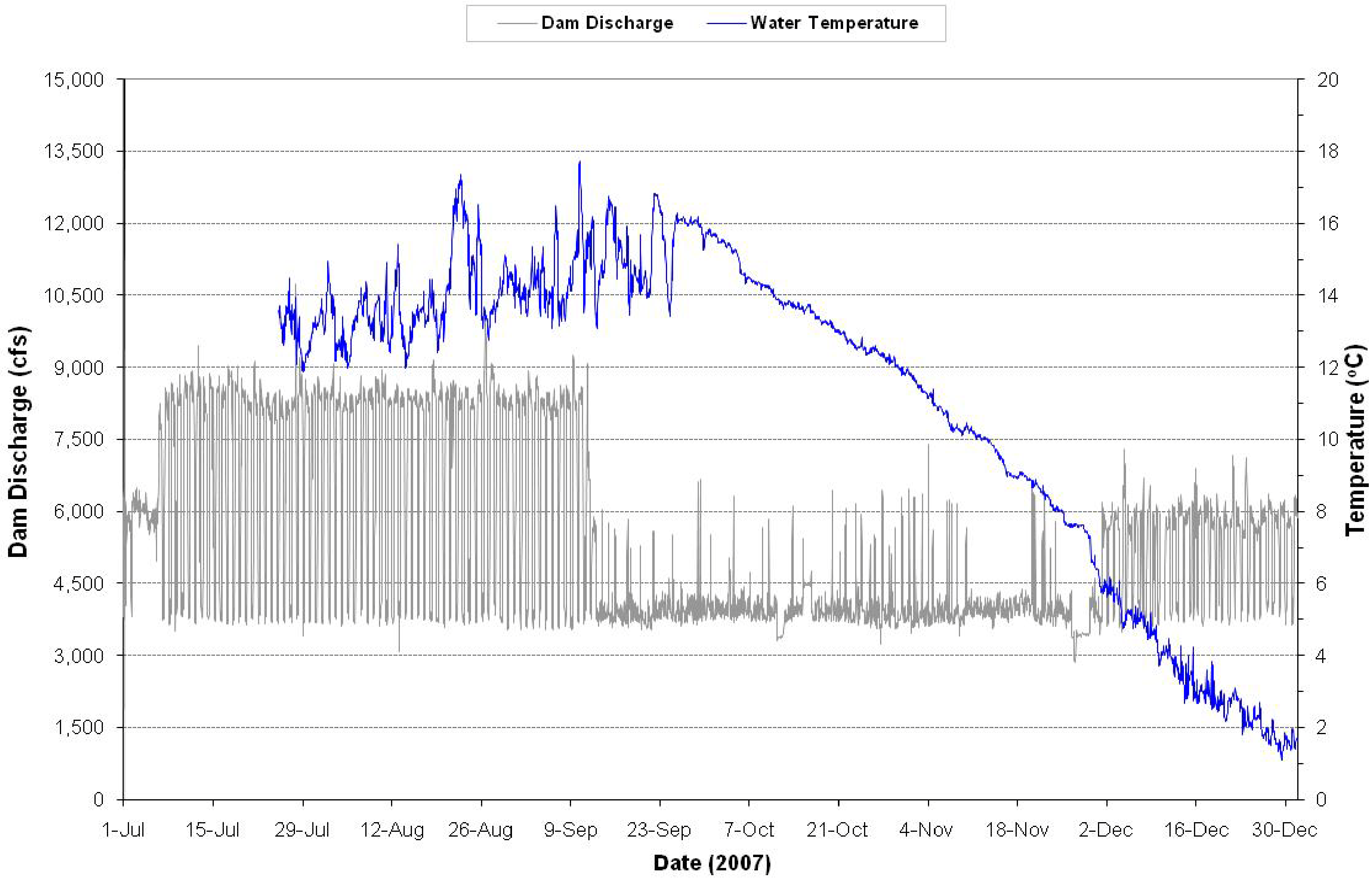

Plate 42. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

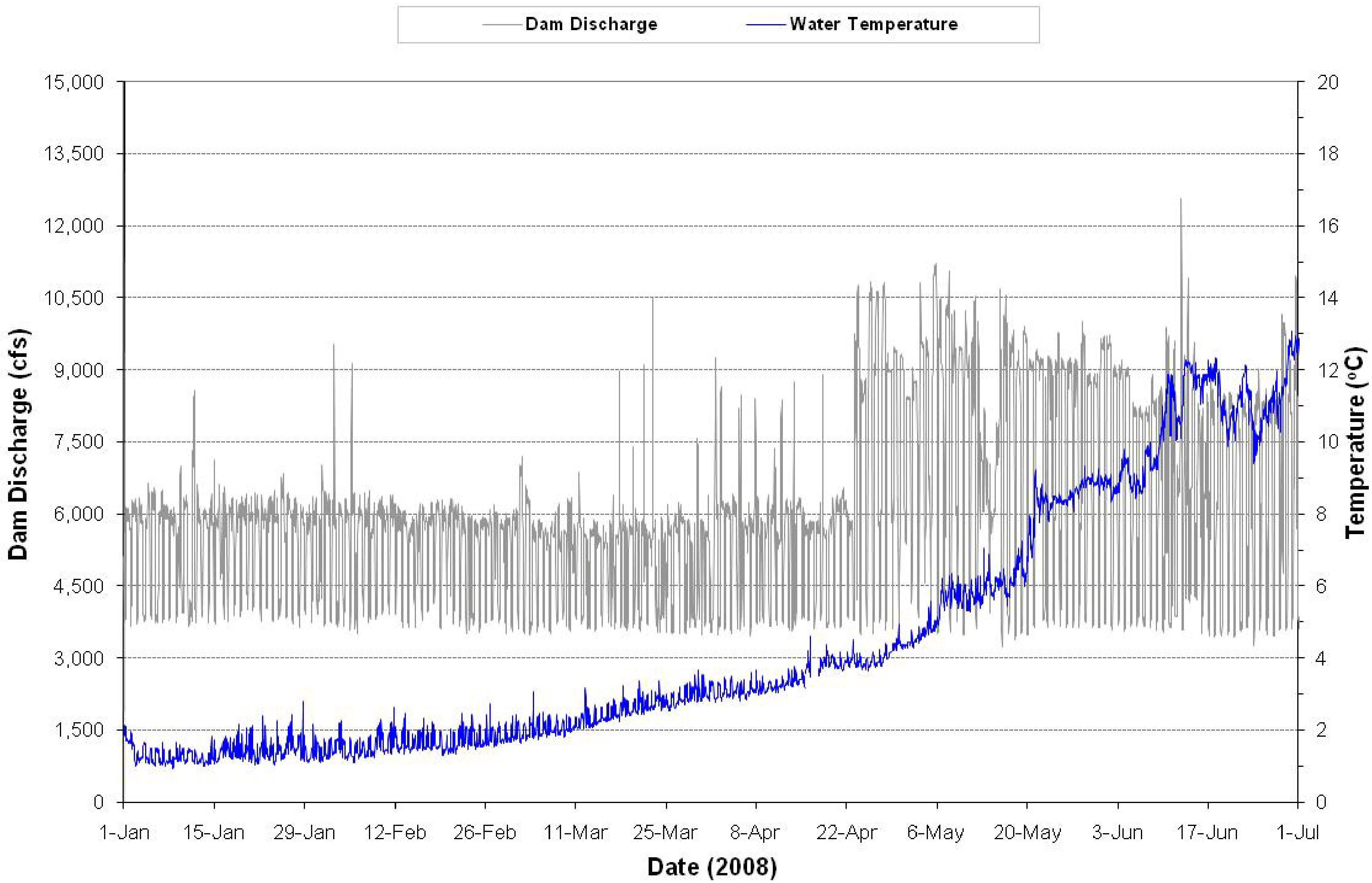

Plate 43. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2008.

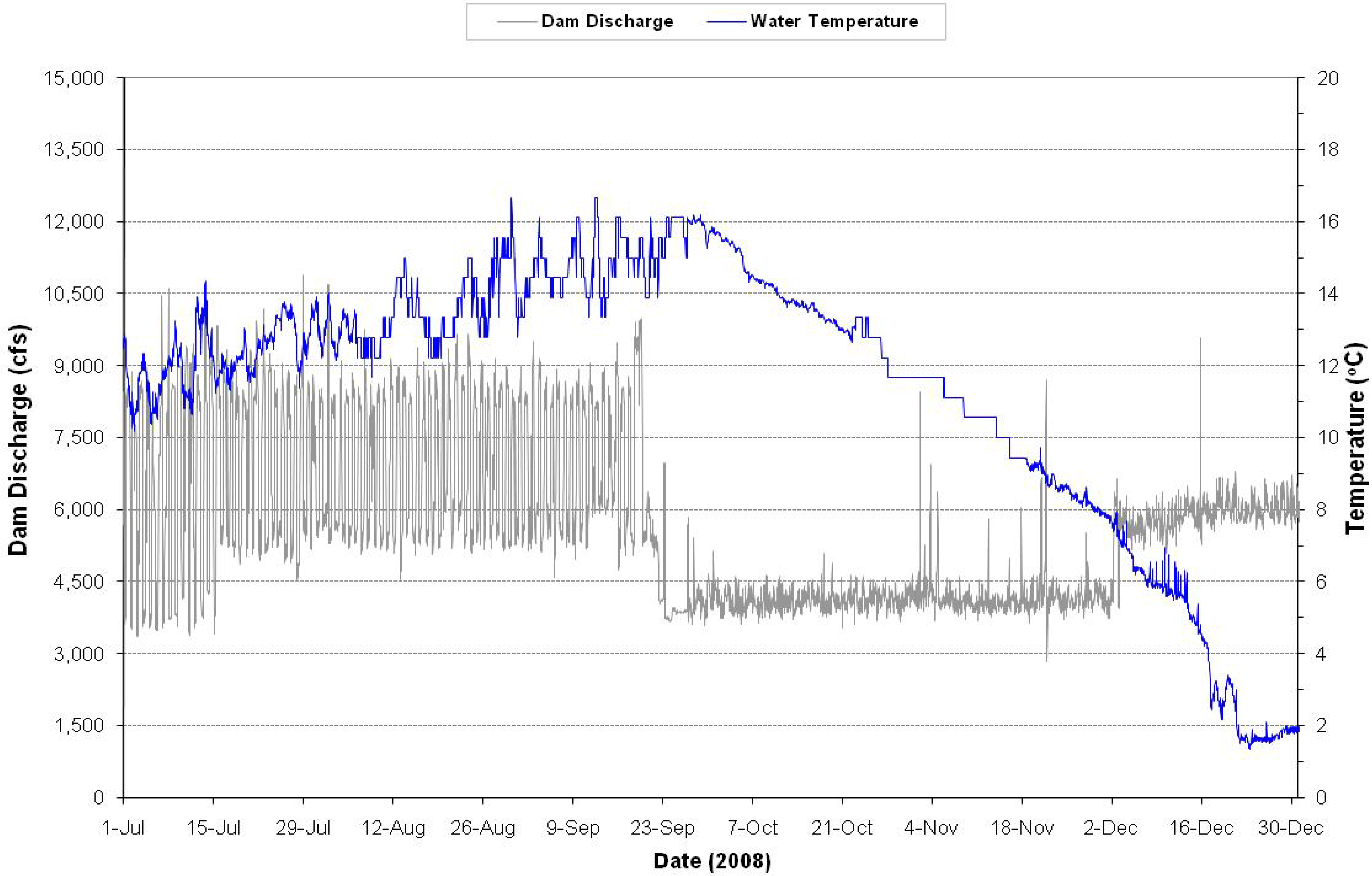

Plate 44. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2008.

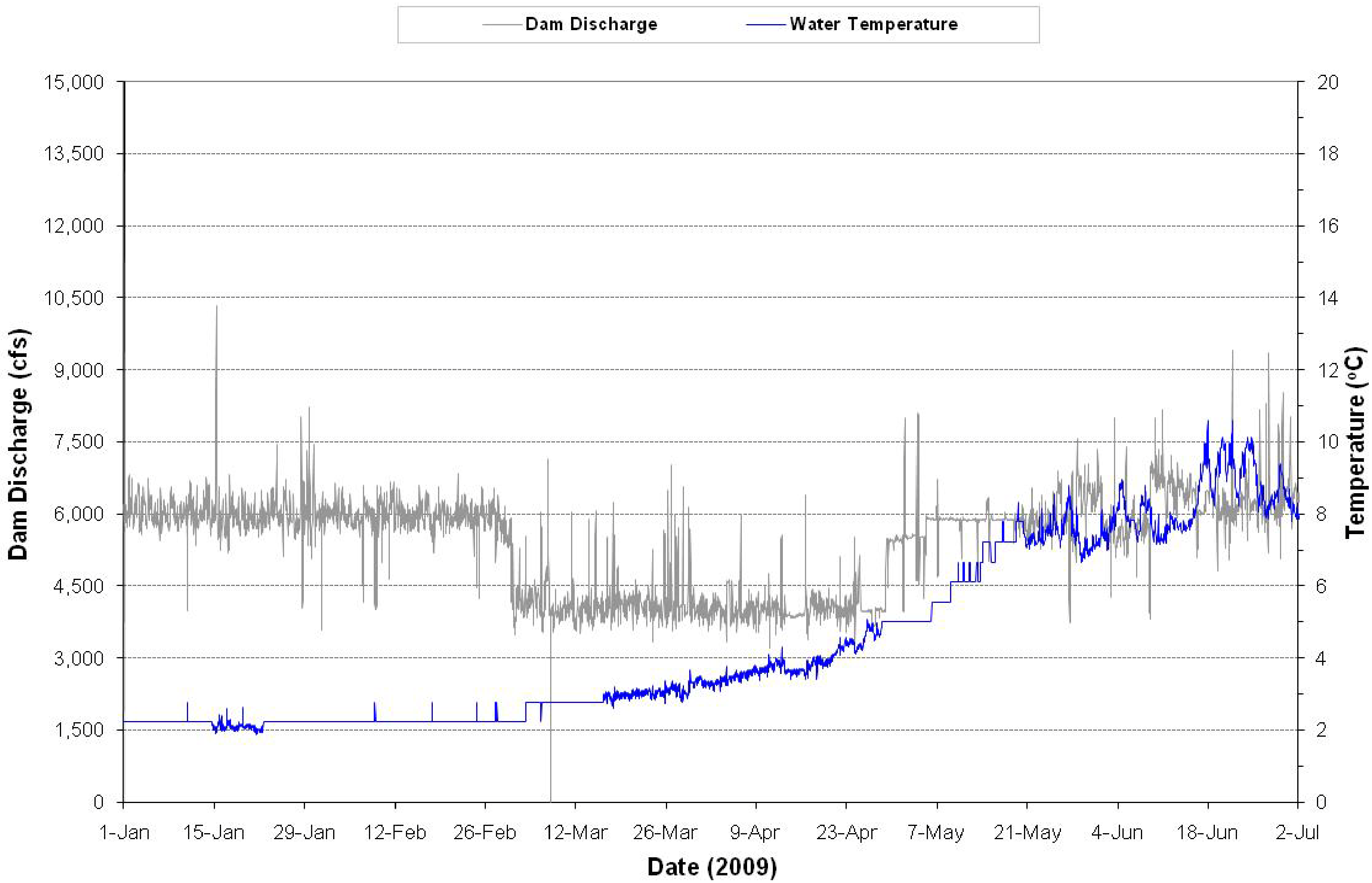

Plate 45. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2009.

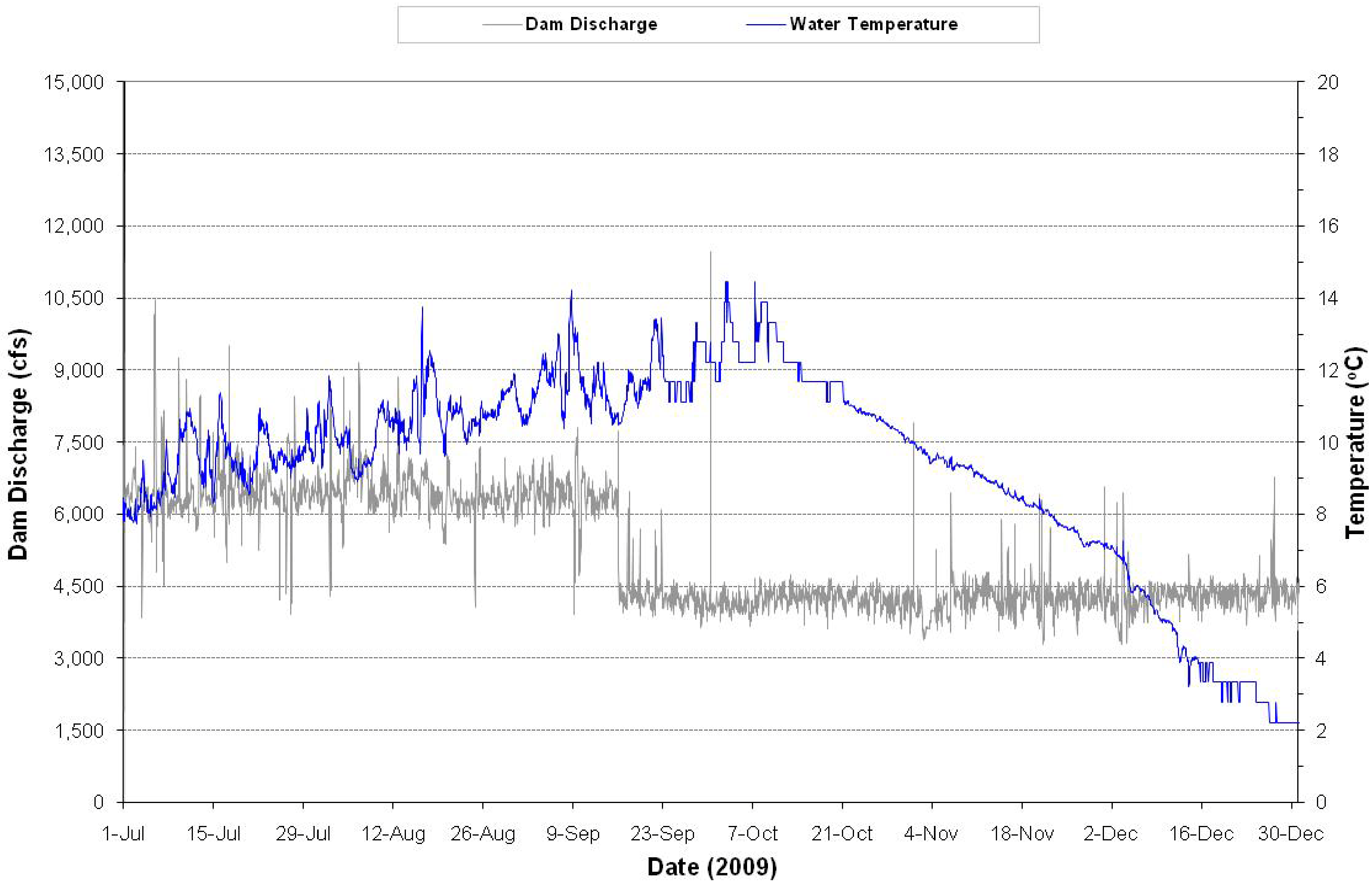

Plate 46. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2009.

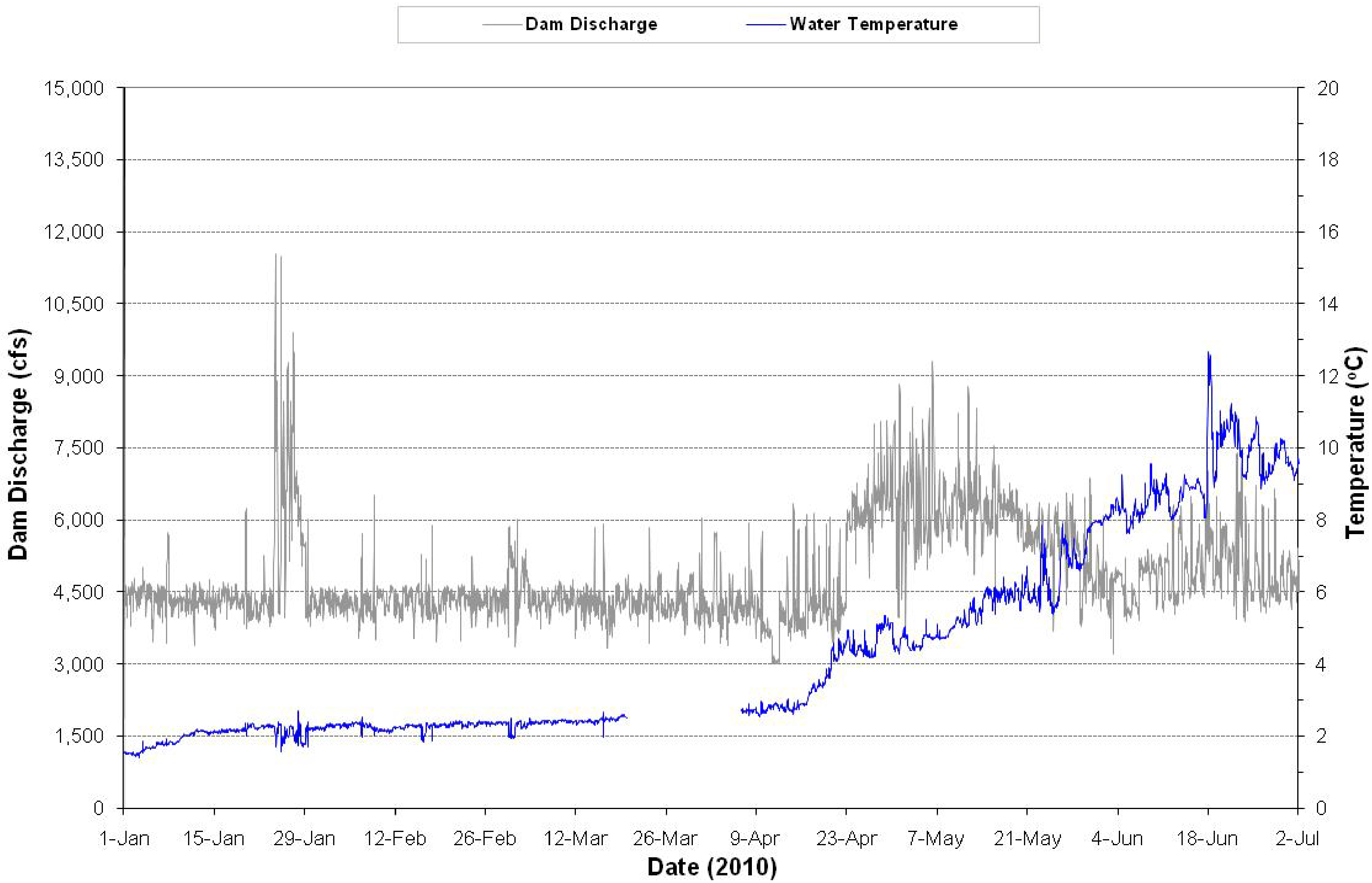

Plate 47. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2010.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

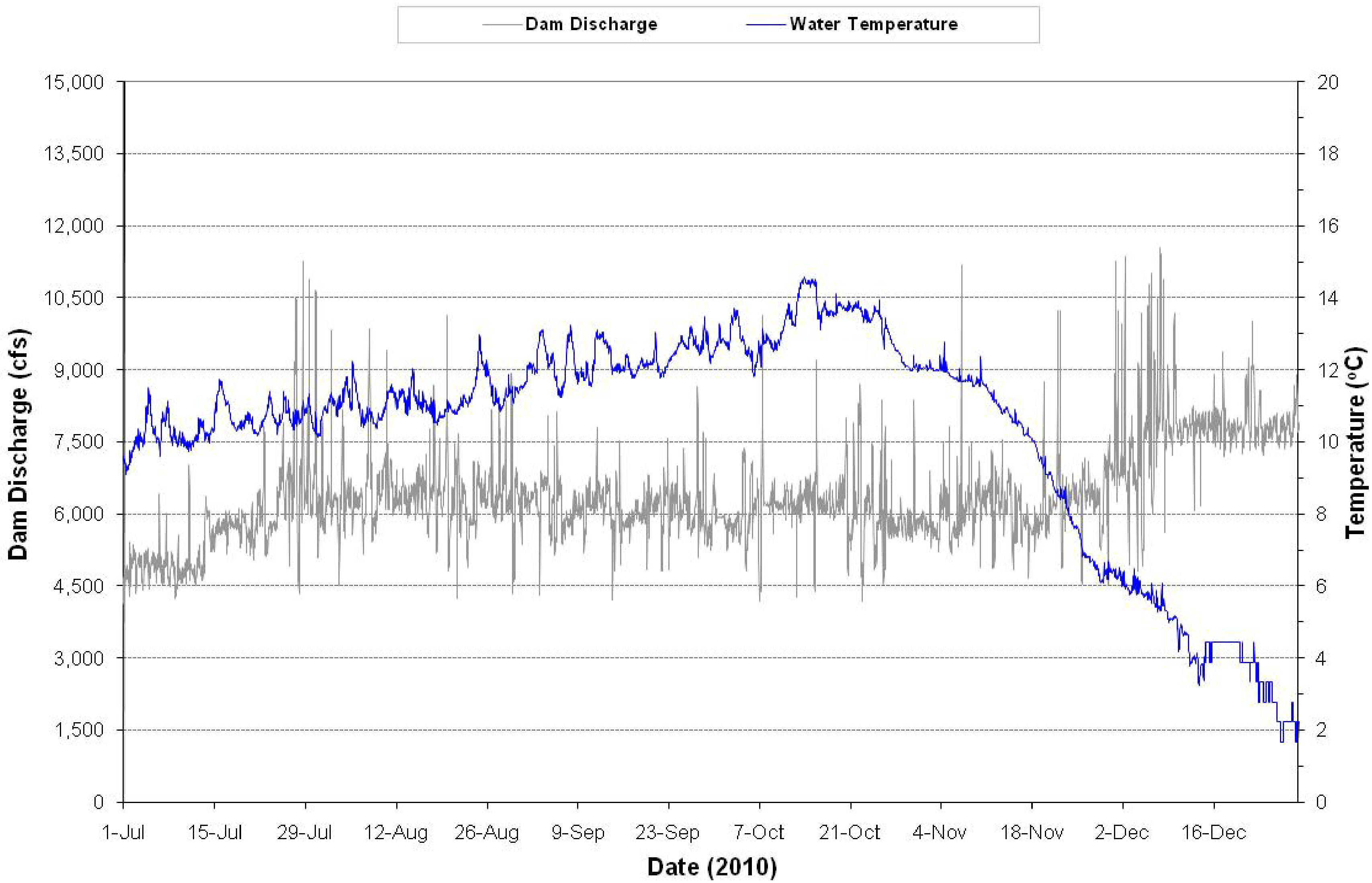

Plate 48. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2010.

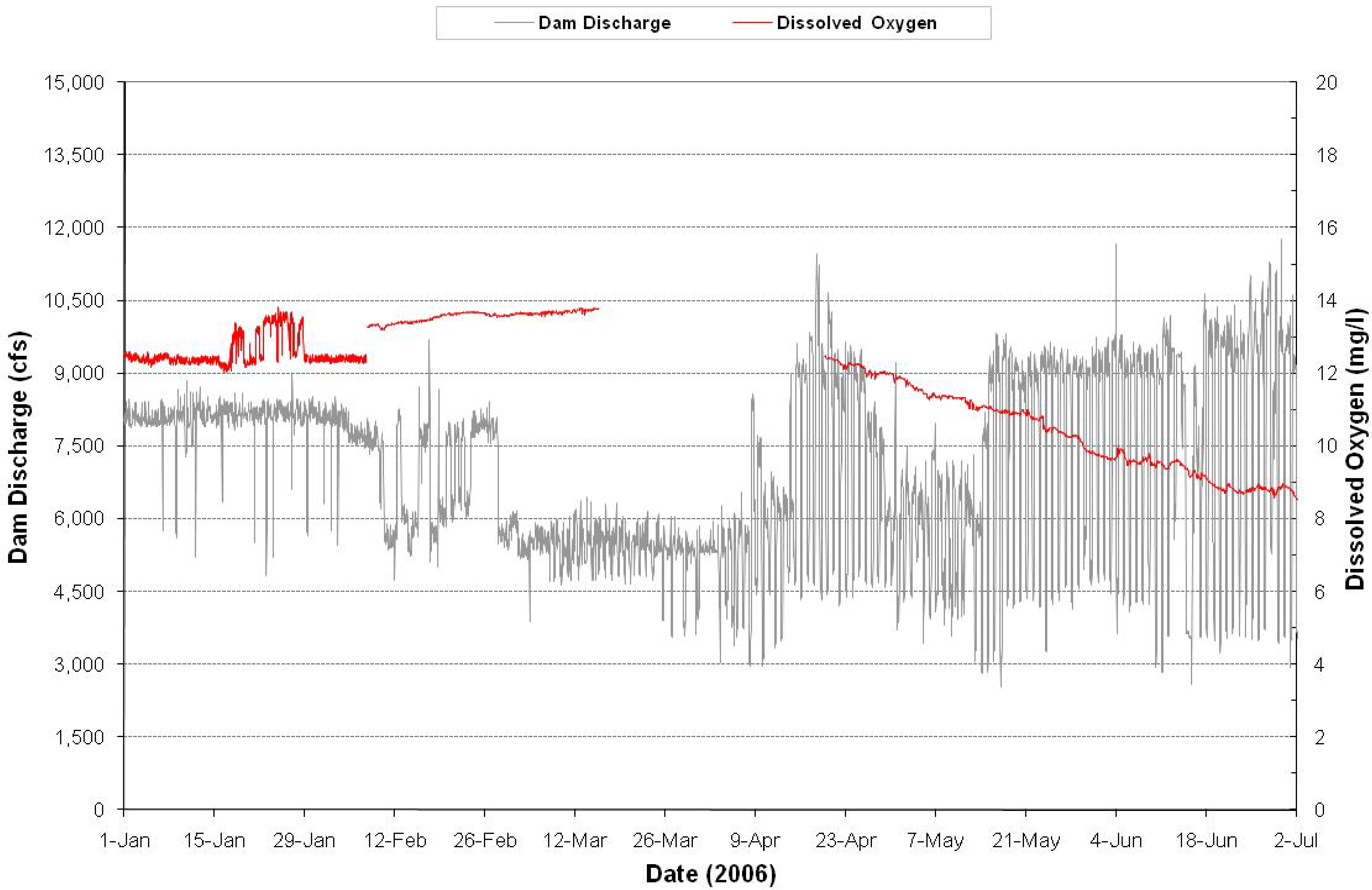

Plate 49. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2006.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

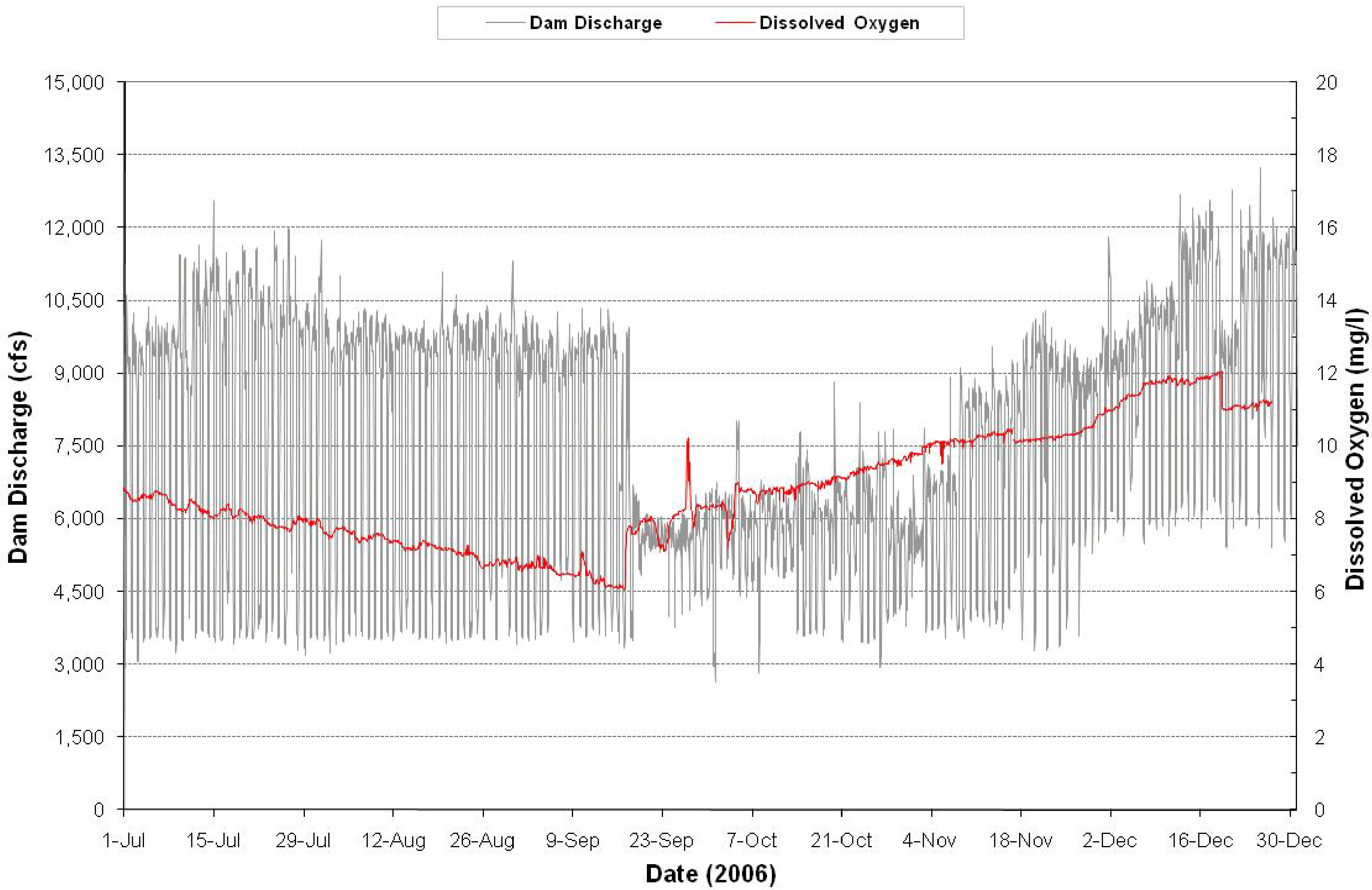

Plate 50. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2006.

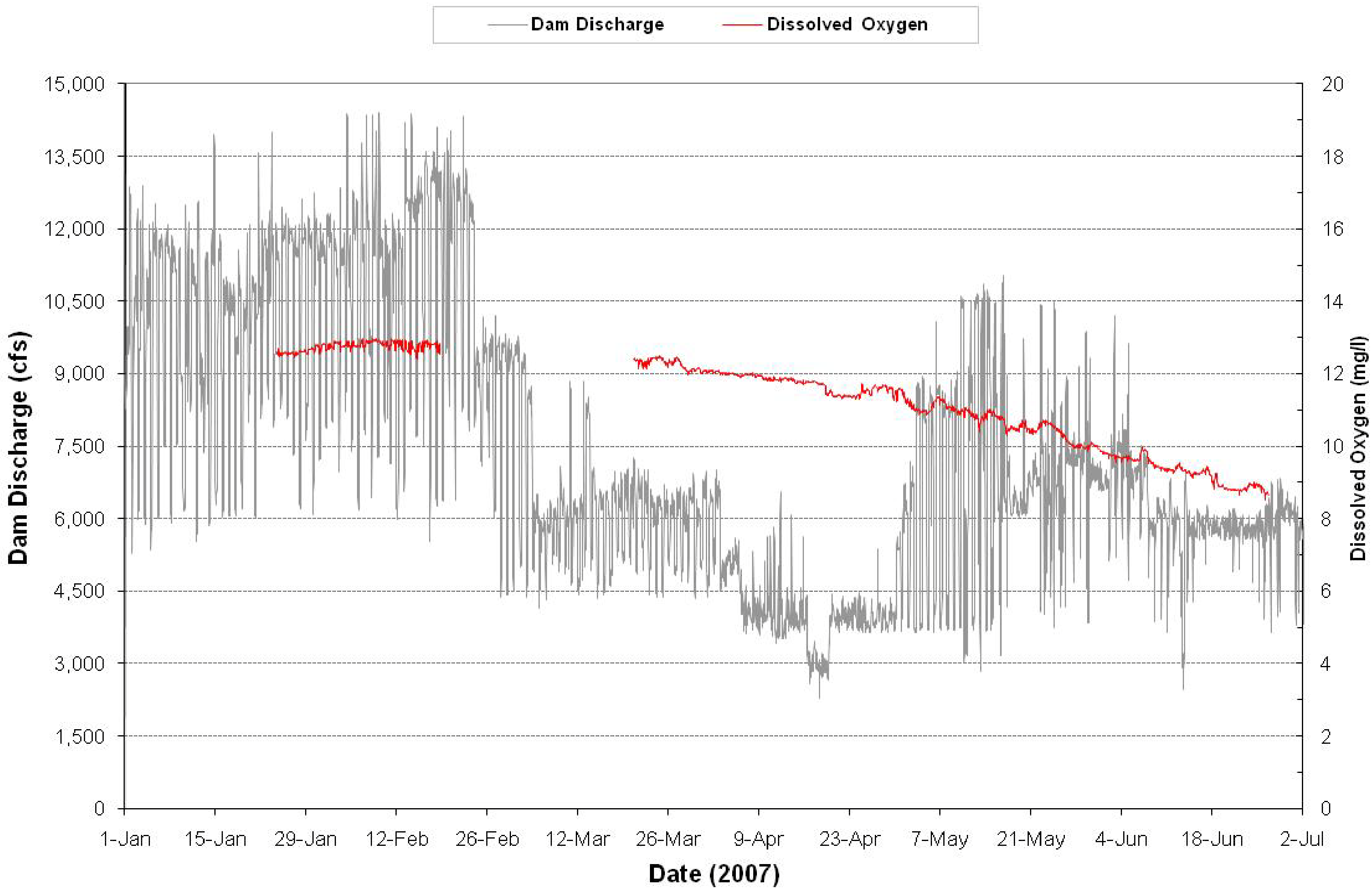

Plate 51. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2007.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

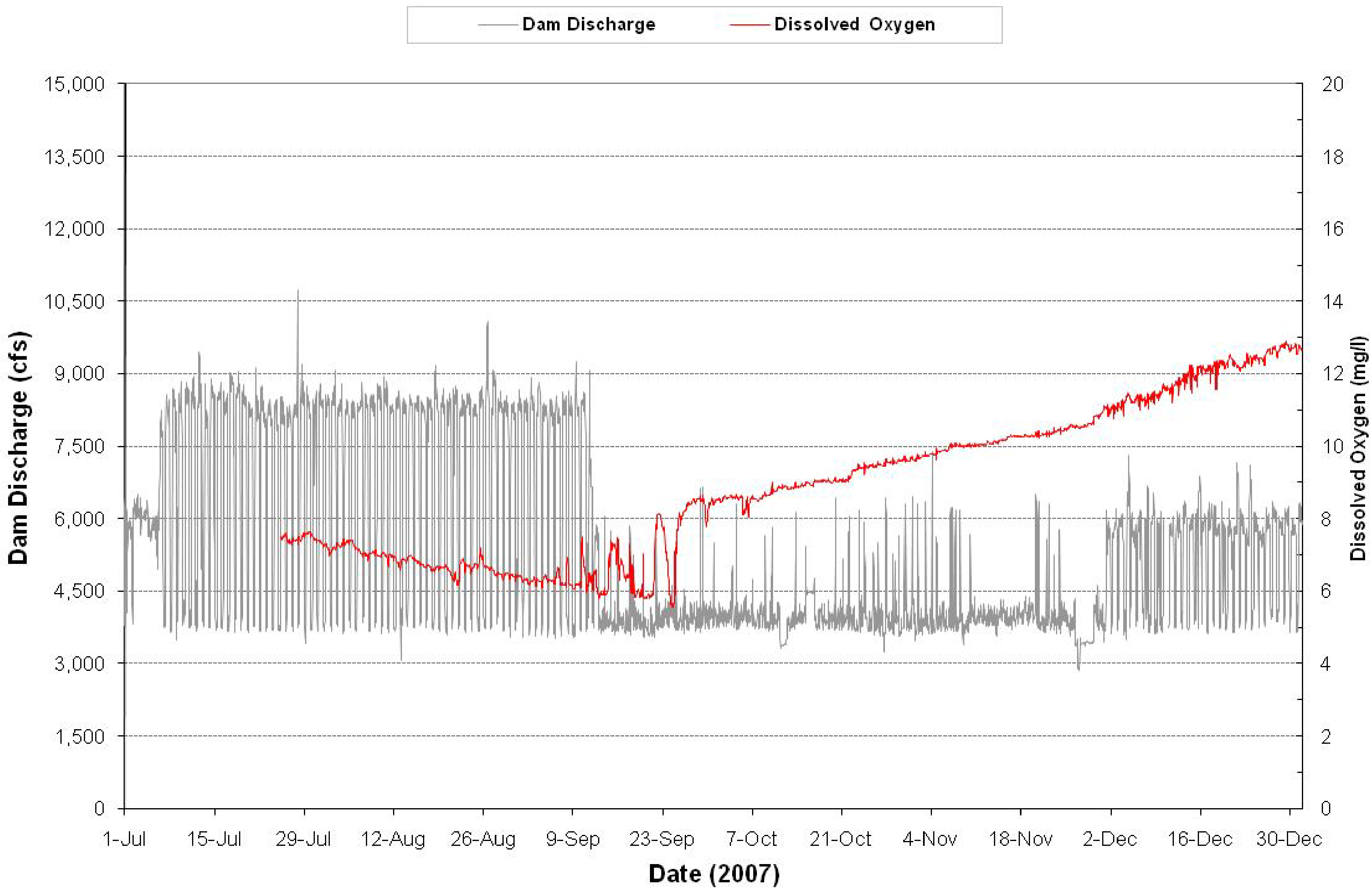

Plate 52. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

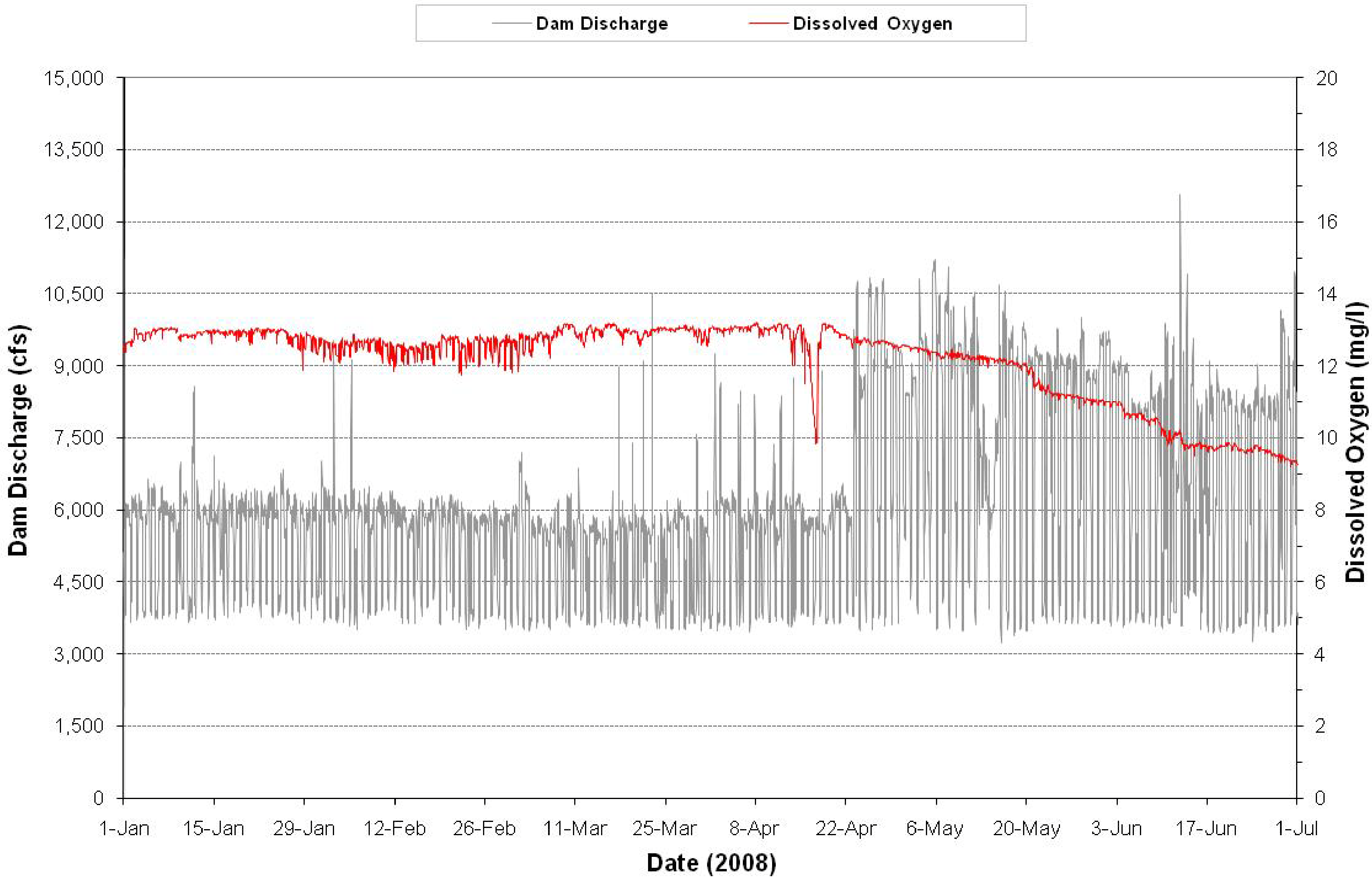

Plate 53. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2008.

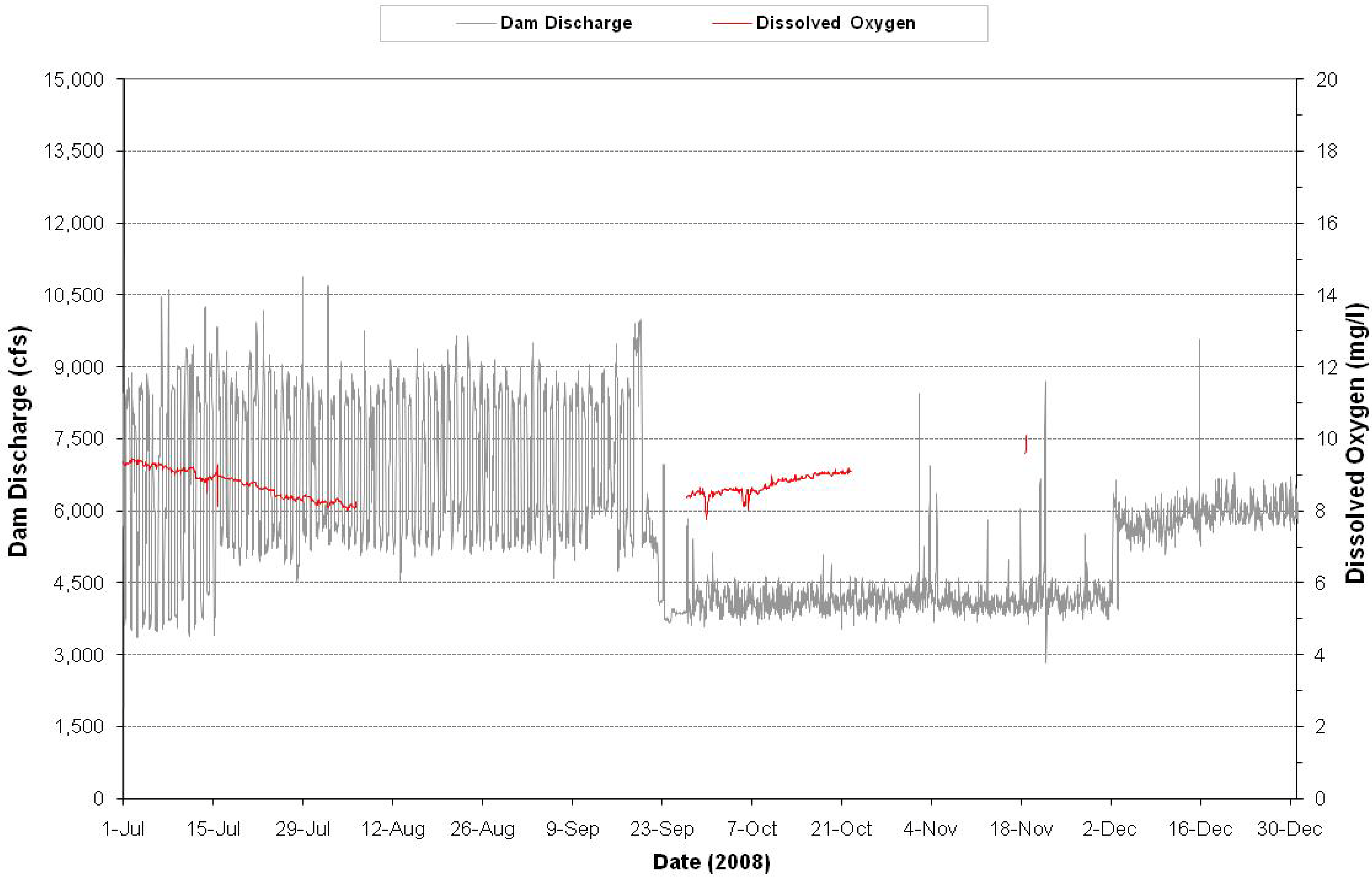

Plate 54. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2008.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

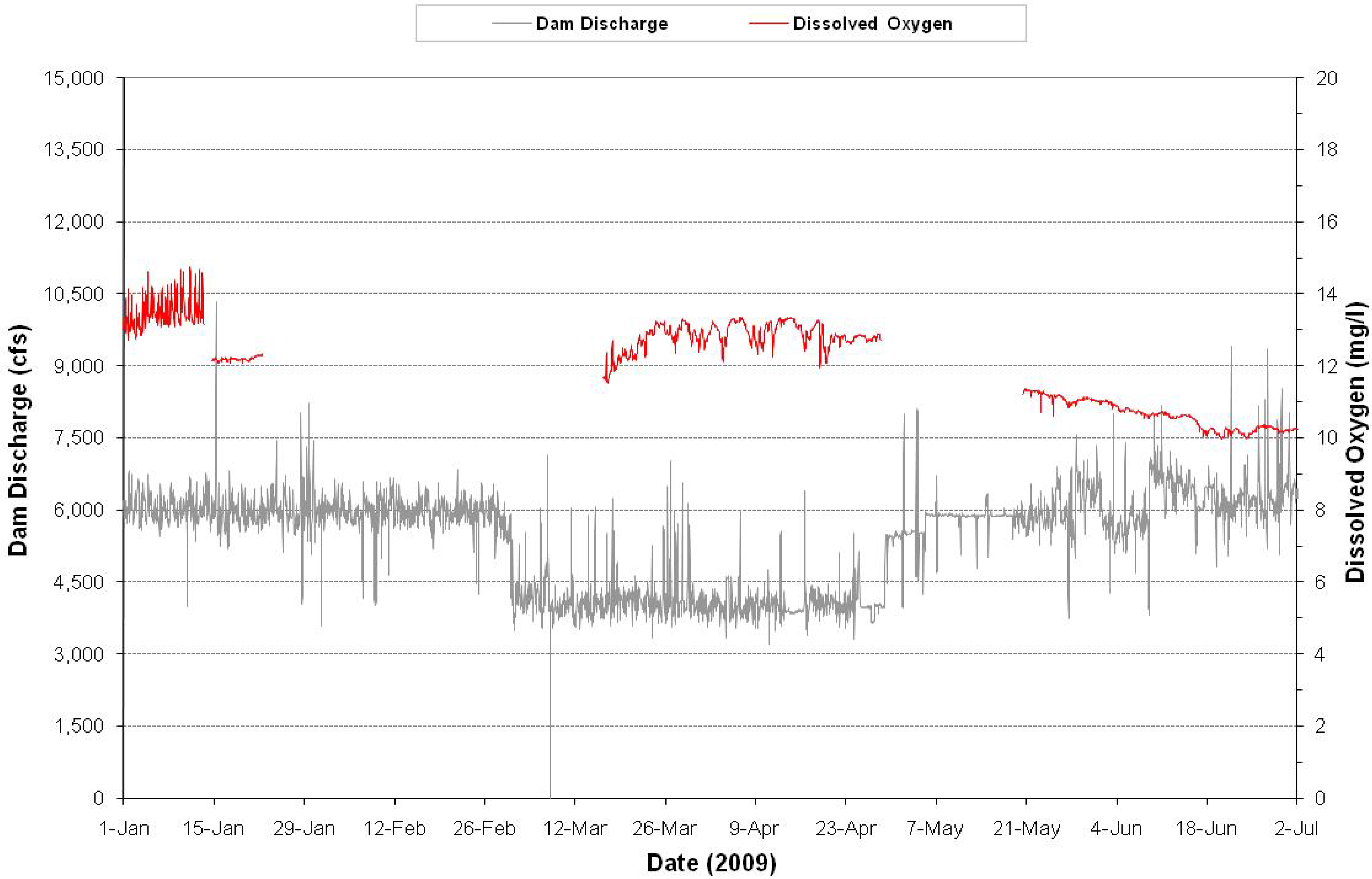

Plate 55. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2009.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

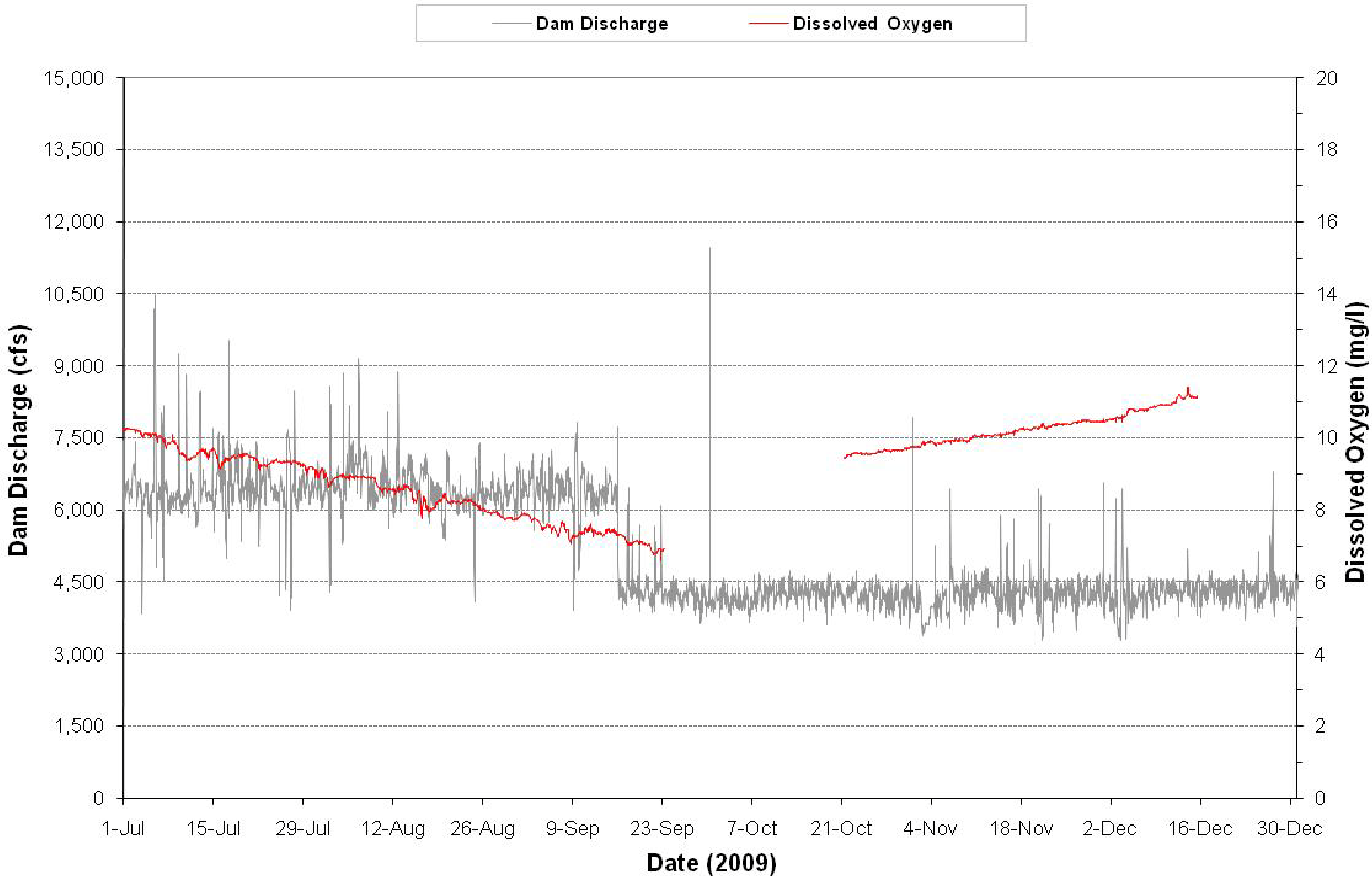

Plate 56. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2009.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

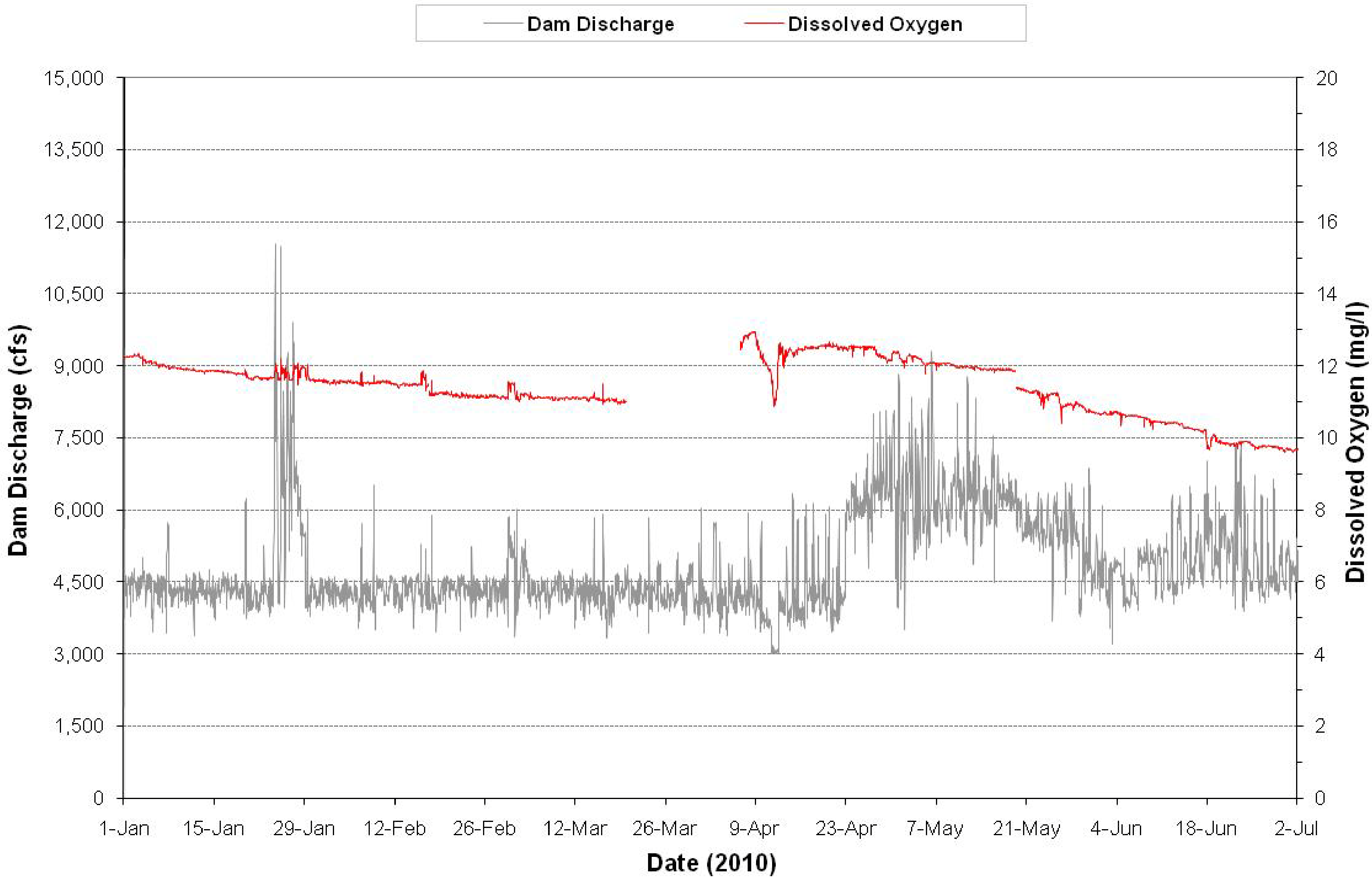

Plate 57. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2010.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

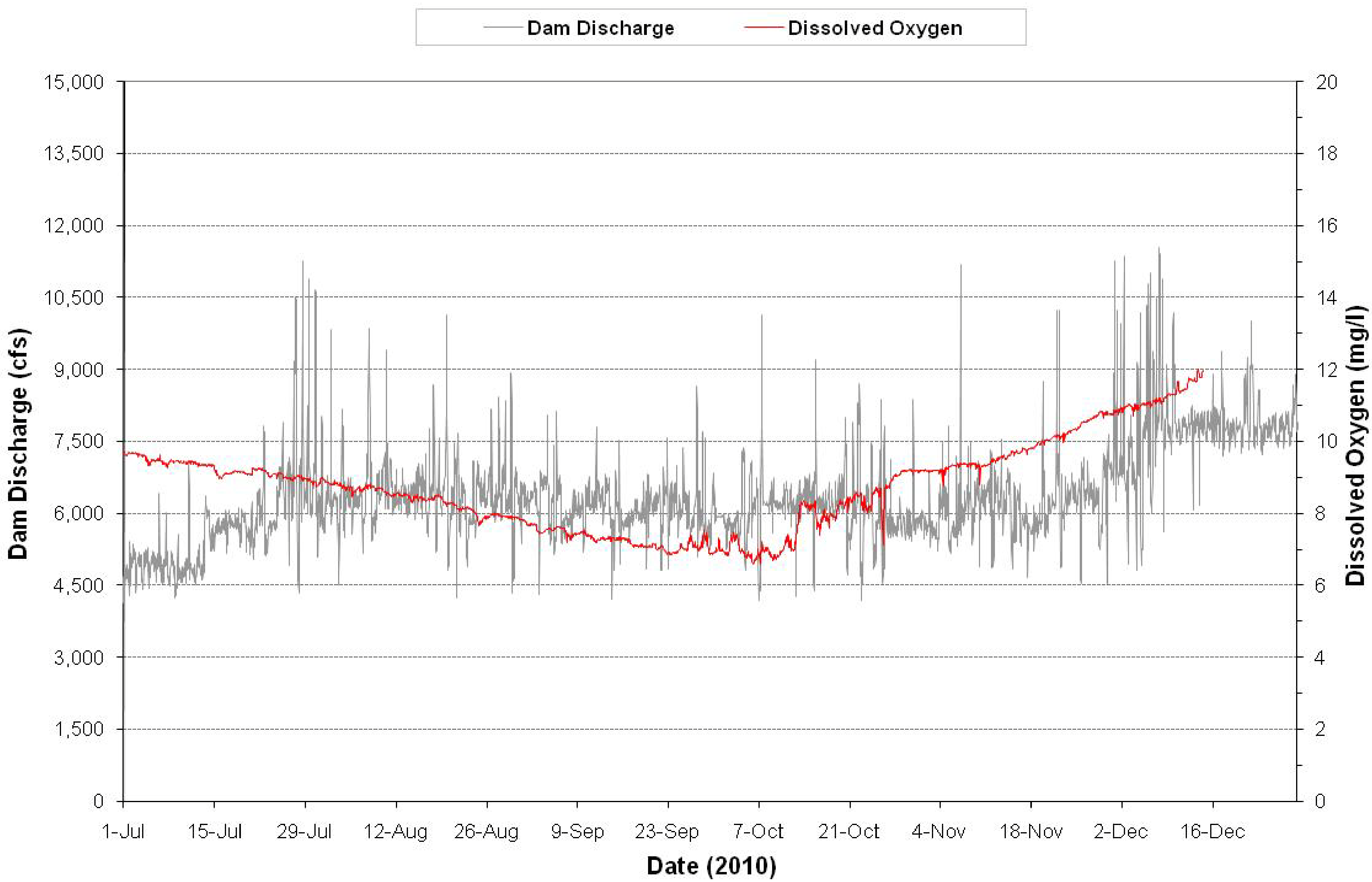

Plate 58. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2009.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

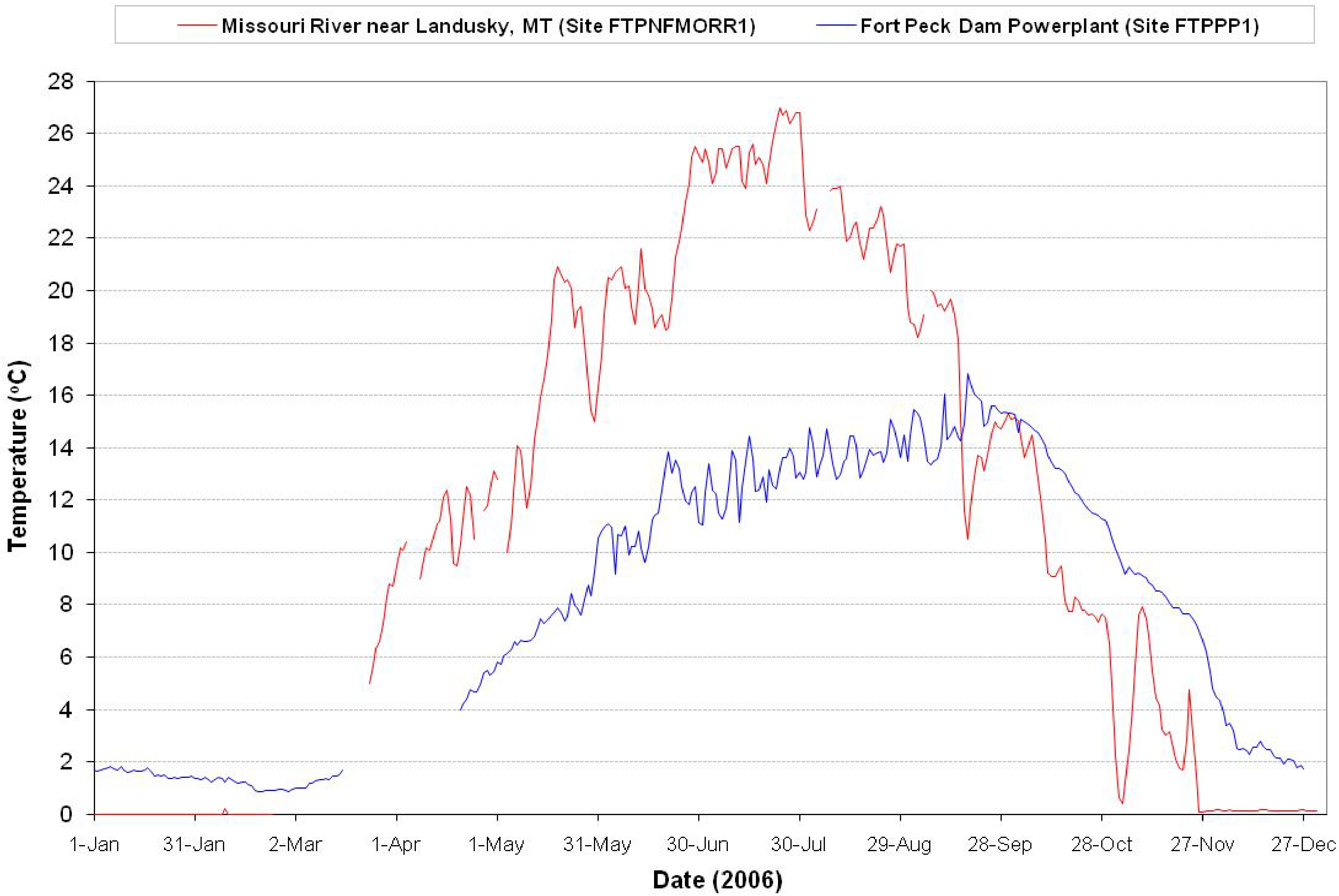

Plate 59. Mean daily water temperatures monitored at the Fort Peck Powerplant (i.e., site FTPPP1) and the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) during 2006.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

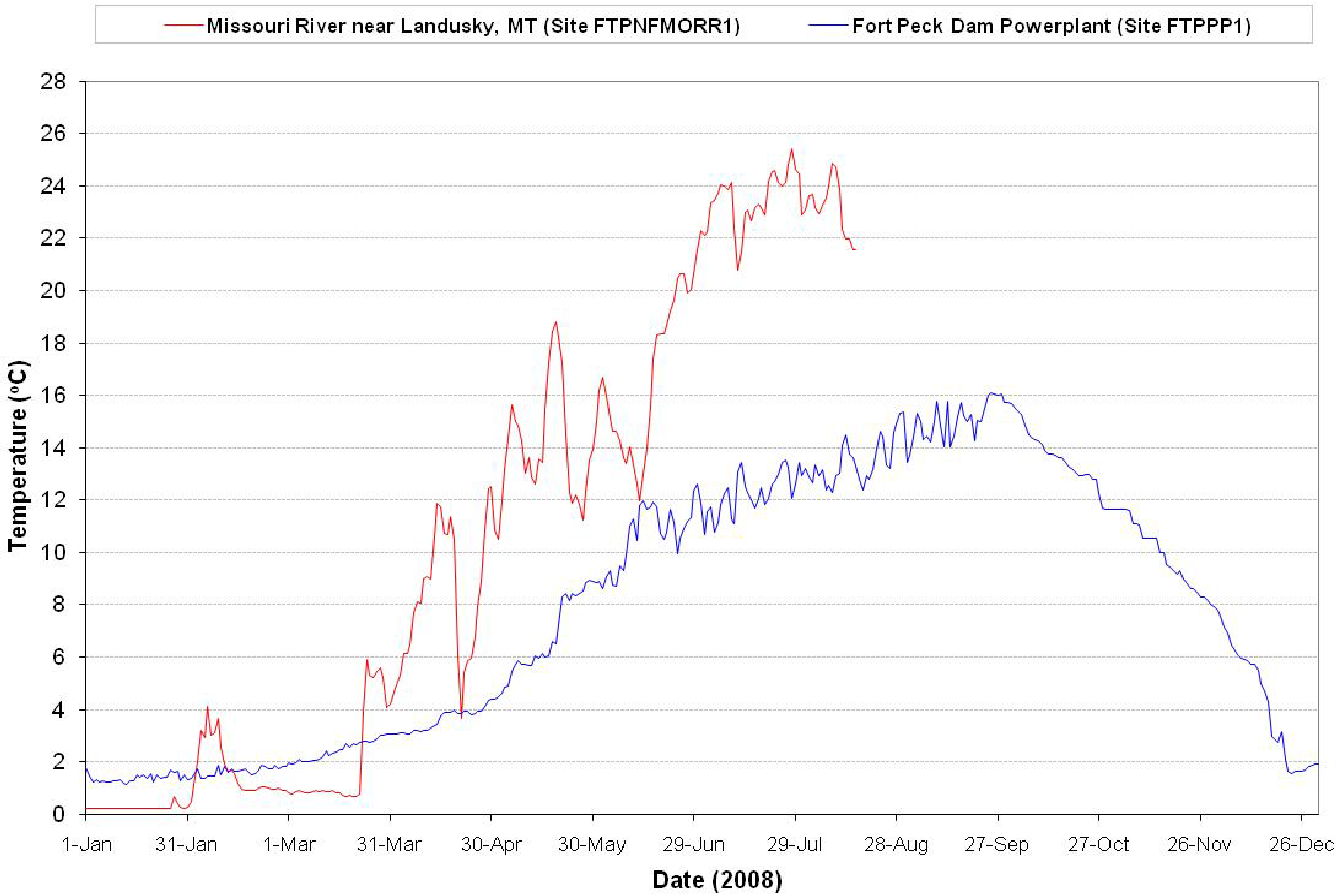

Plate 60. Mean daily water temperatures monitored at the Fort Peck Powerplant (i.e., site FTPPP1) and the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) during 2008.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

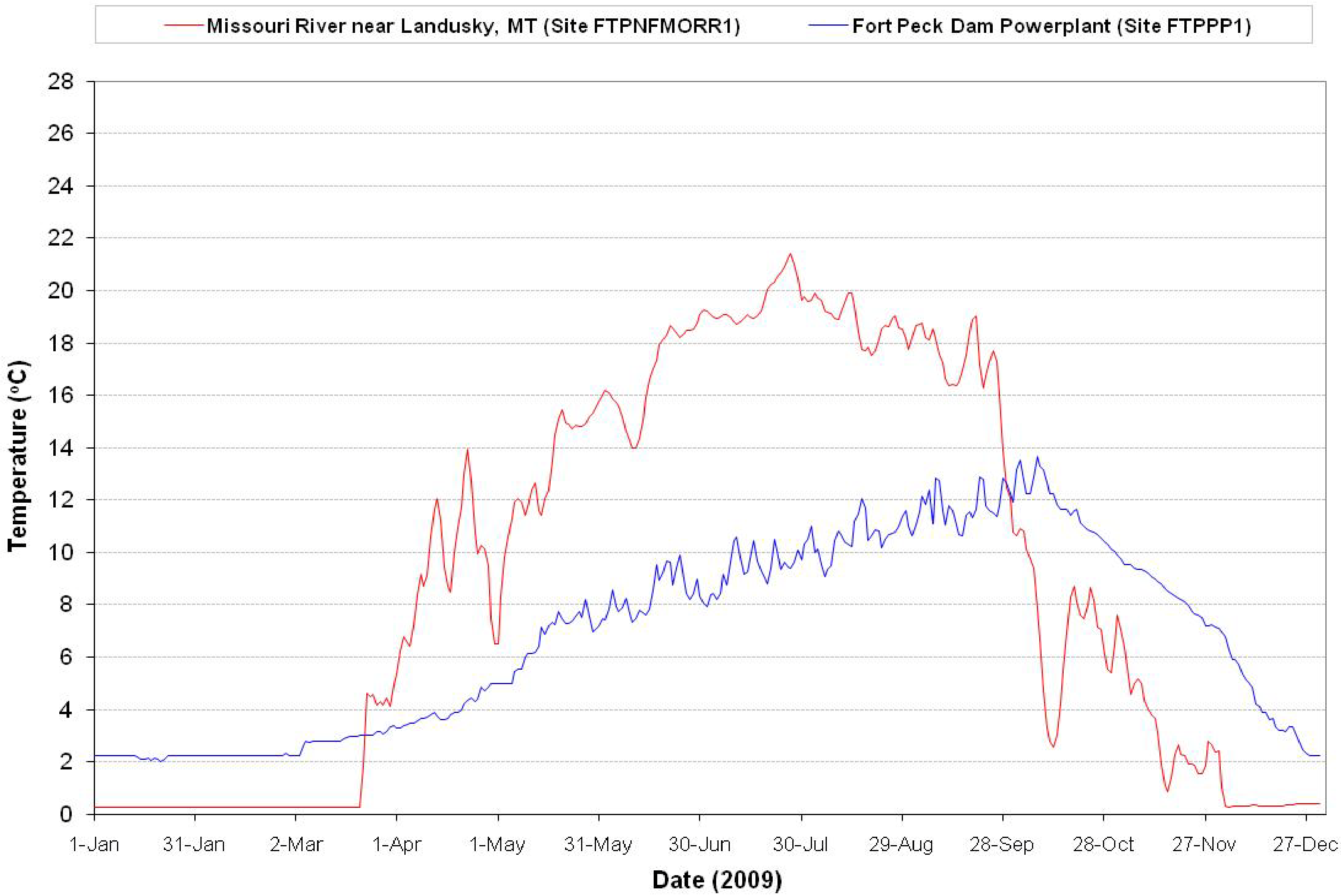

Plate 61. Mean daily water temperatures monitored at the Fort Peck Powerplant (i.e., site FTPPP1) and the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) during 2009.

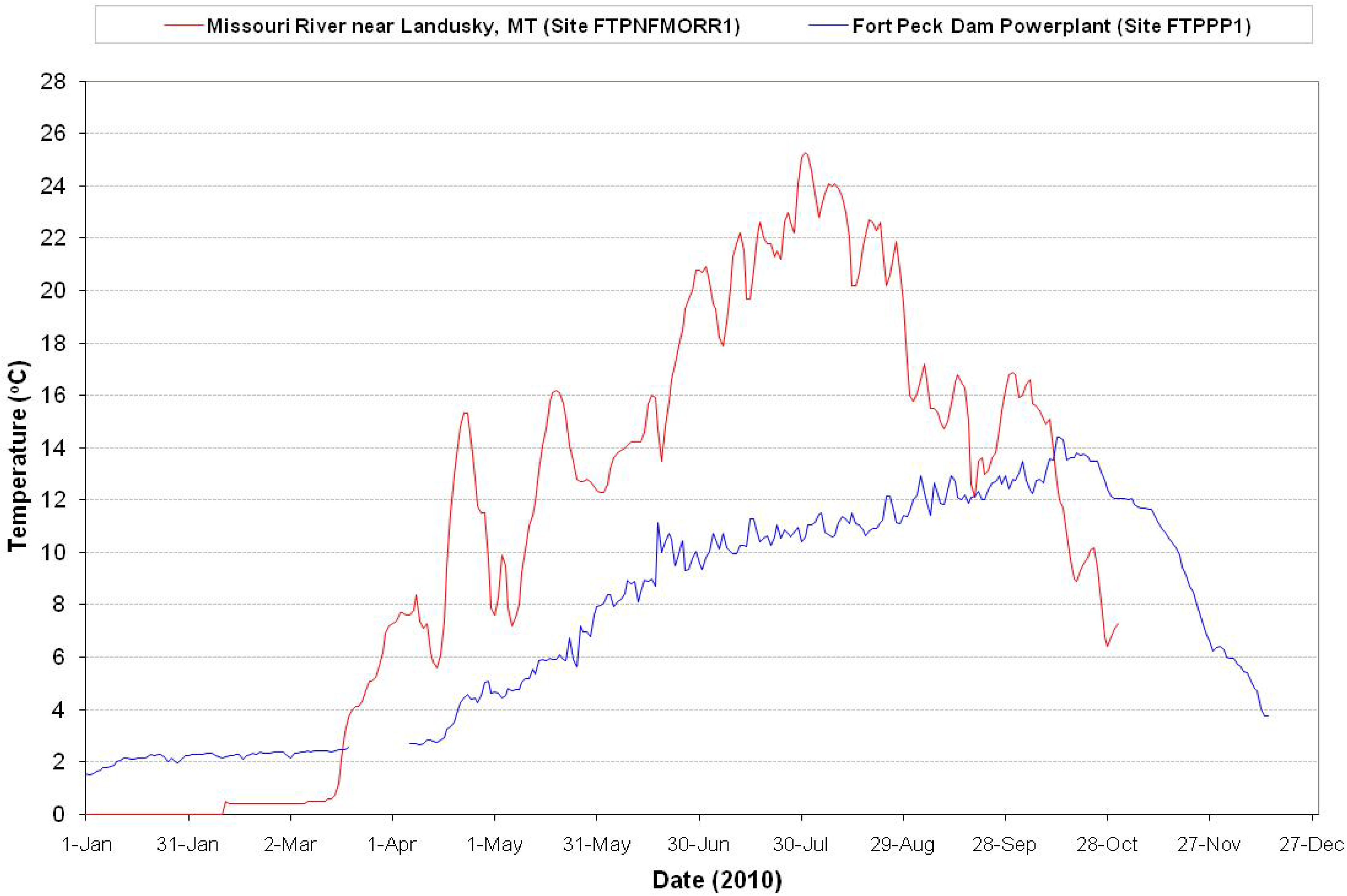

Plate 62. Mean daily water temperatures monitored at the Fort Peck Powerplant (i.e., site FTPPP1) and the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) during 2010.

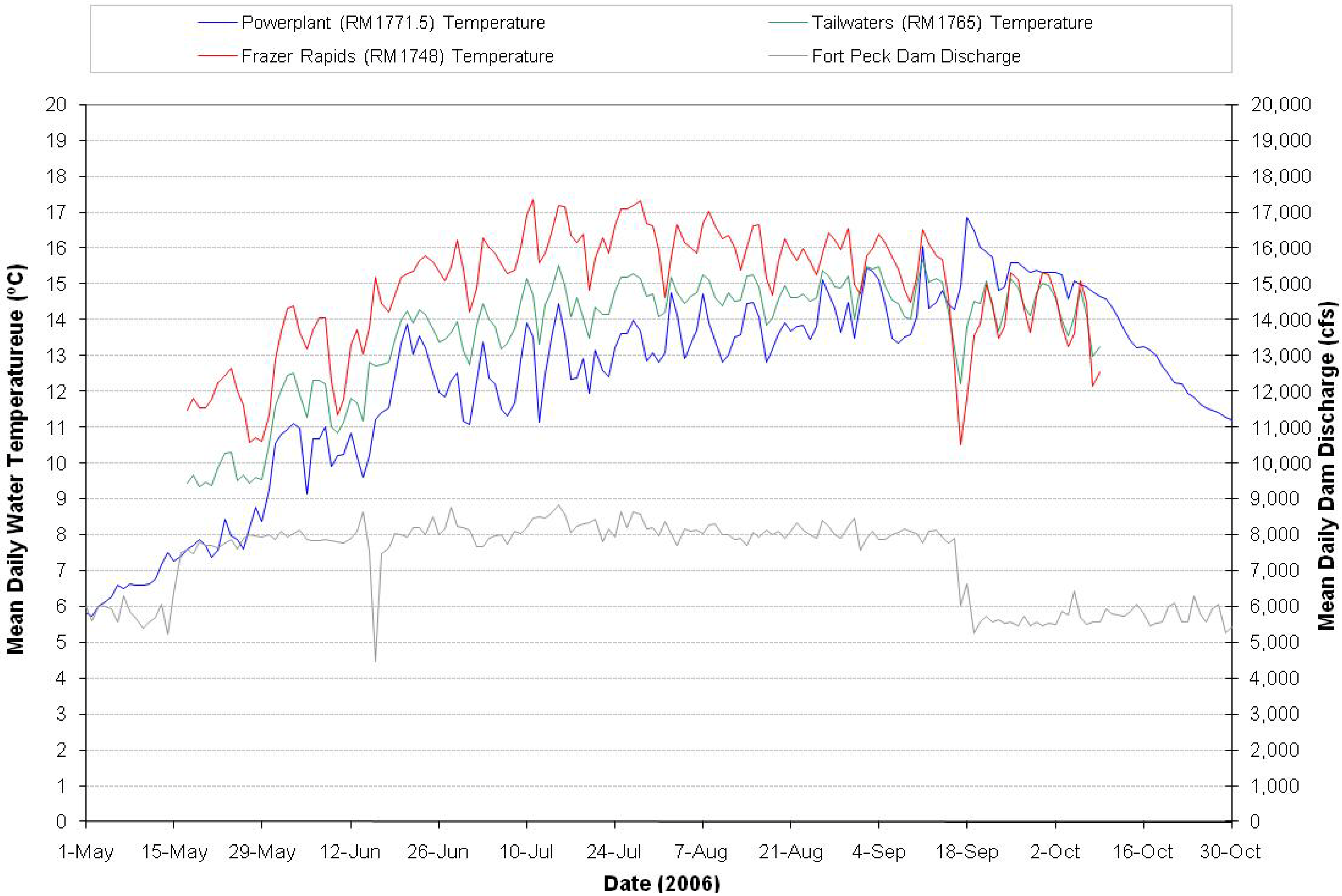

Plate 63. Mean daily water temperature monitored at the Fort Peck powerplant and along the Missouri River downstream of Fort Peck Dam at the Fort Peck Dam tailwaters and Frazer Rapids and the mean daily discharge of Fort Peck Dam from May through October during 2006.

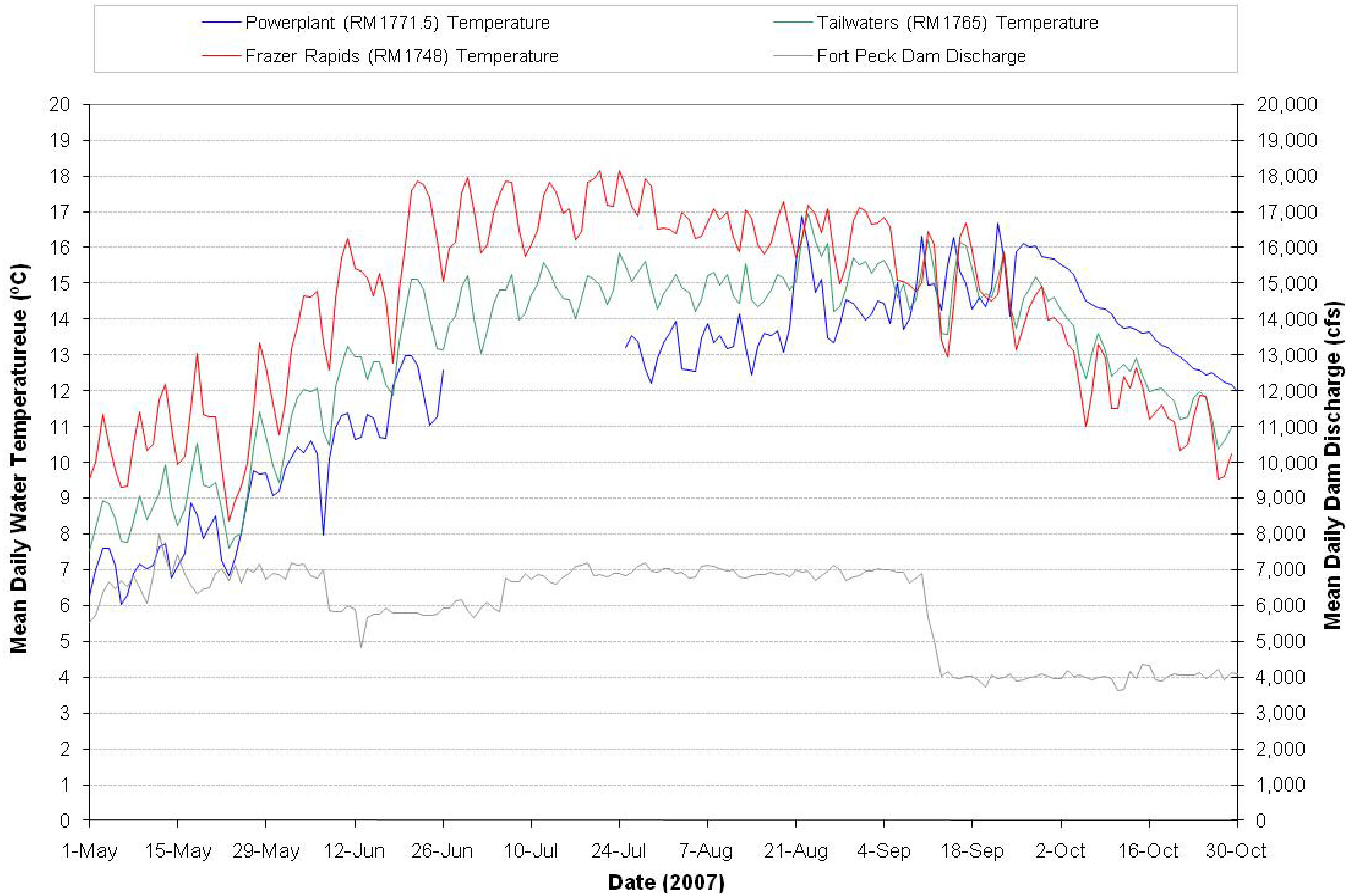

Plate 64. Mean daily water temperature monitored at the Fort Peck powerplant and along the Missouri River downstream of Fort Peck Dam at the Fort Peck Dam tailwaters and Frazer Rapids and the mean daily discharge of Fort Peck Dam from May through October during 2007.

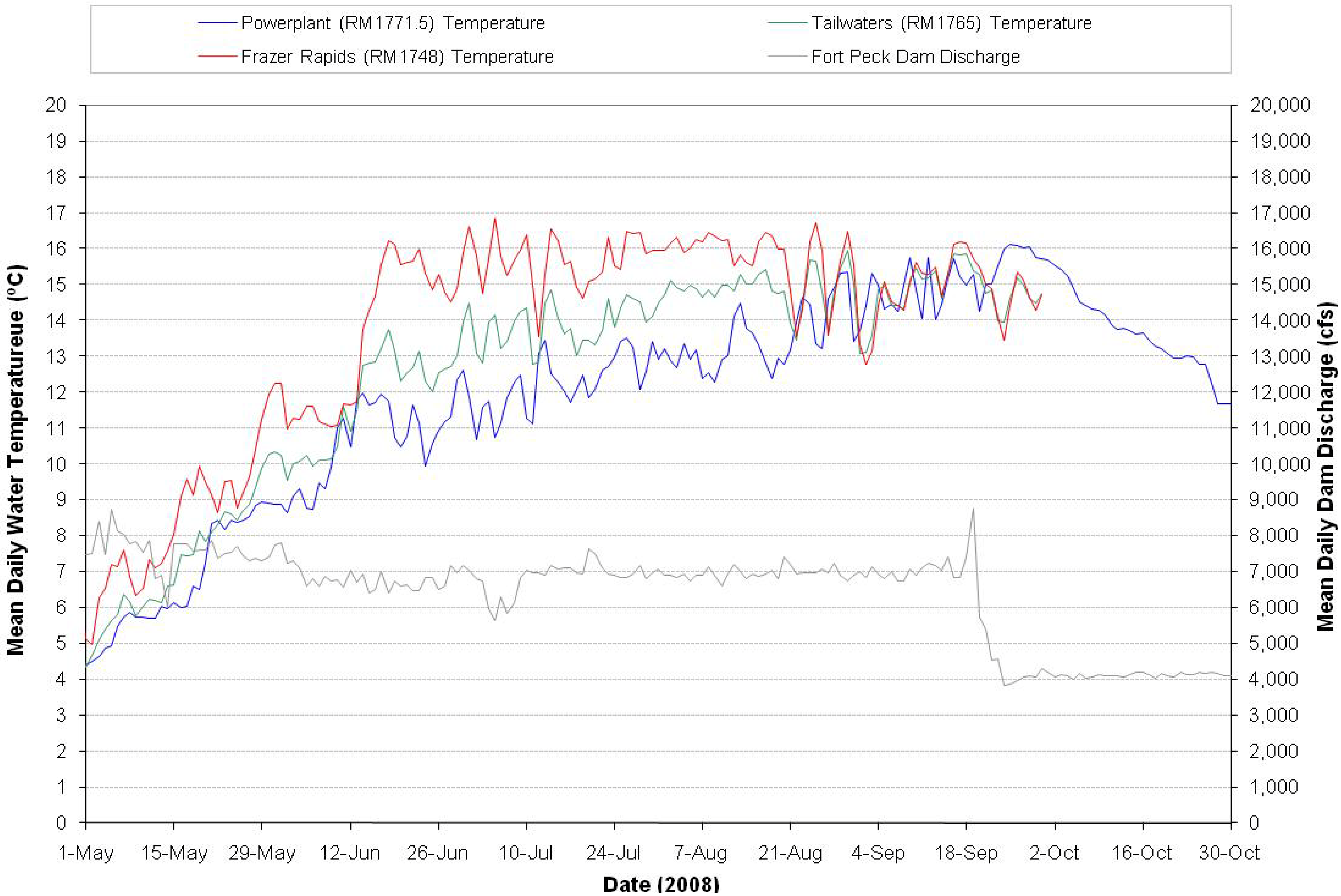

Plate 65. Mean daily water temperature monitored at the Fort Peck powerplant and along the Missouri River downstream of Fort Peck Dam at the Fort Peck Dam tailwaters and Frazer Rapids and the mean daily discharge of Fort Peck Dam from May through October during 2008.

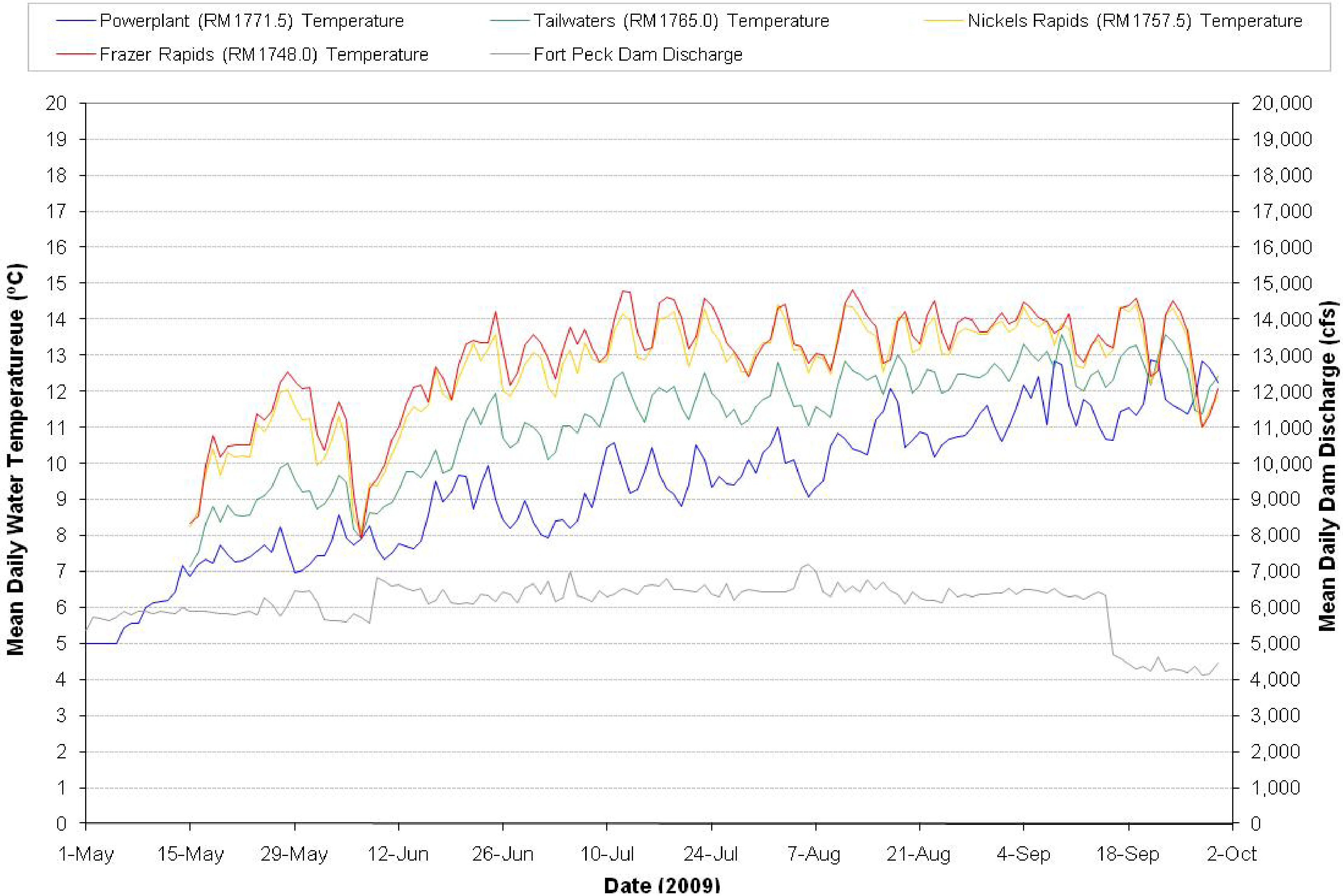

Plate 66. Mean daily water temperature monitored at the Fort Peck powerplant and along the Missouri River downstream of Fort Peck Dam at the Fort Peck Dam tailwaters, Nickels Rapids, and Frazer Rapids and the mean daily discharge of Fort Peck Dam from May through October during 2009.

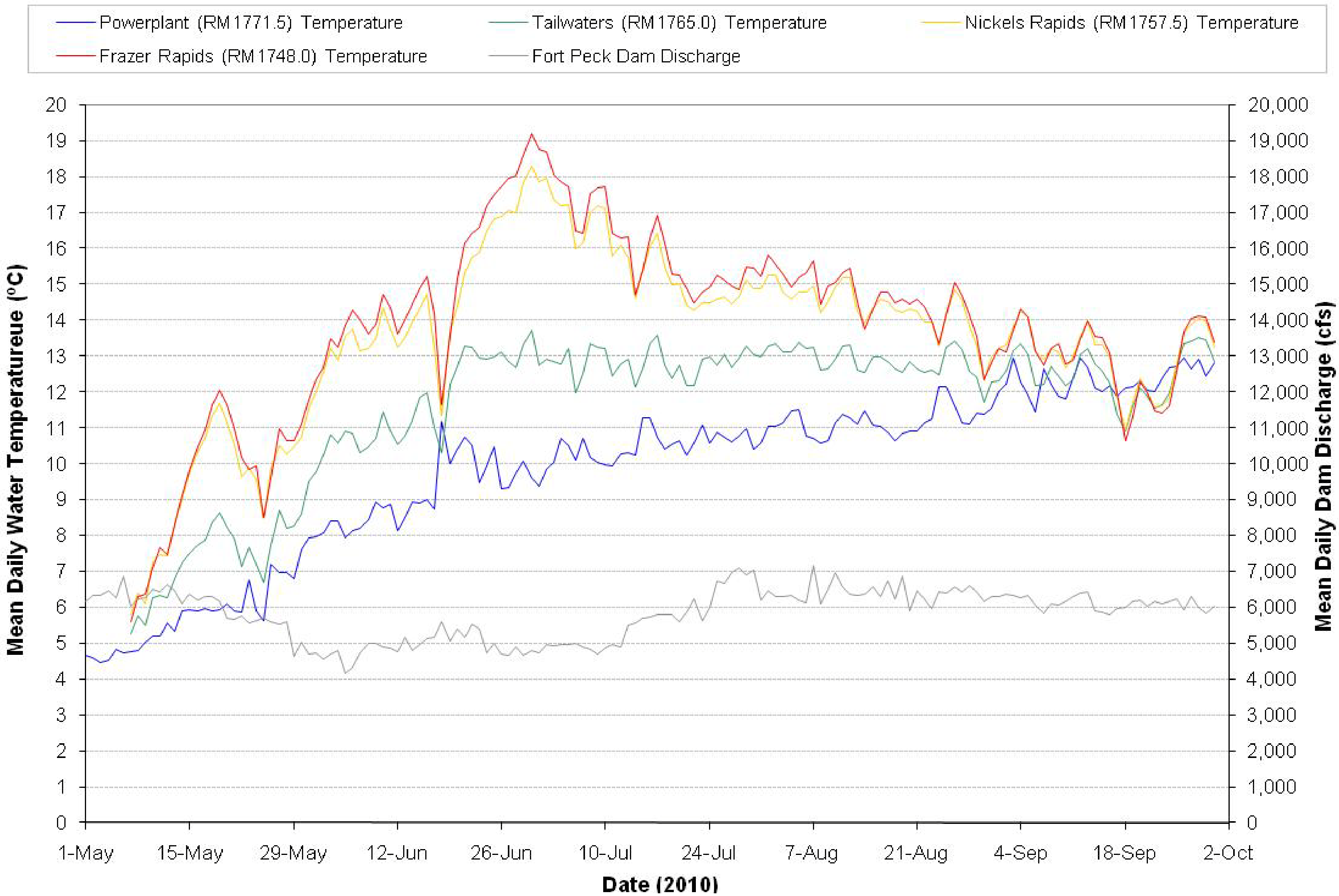

Plate 67. Mean daily water temperature monitored at the Fort Peck powerplant and along the Missouri River downstream of Fort Peck Dam at Fort Peck Dam tailwaters, Nickels Rapids, and Frazer Rapids and the mean daily discharge of Fort Peck Dam from May through October during 2010.

Plate 68. Summary of monthly (May through September) water quality conditions monitored in Lake Sakakawea near Garrison Dam (Site GARLK1390A) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	27	1825.6	1817.8	1807.4	1850.5	-----	-----	-----
Water Temperature (°C)	0.1	1,186	13.4	14.4	4.4	23.4	29.4[1,3]	0	0%
Hypolimnion Water Temperature (°C)[E]	0.1	353	11.4	11.5	5.6	17.3	15.0[2,3]	25	8%
Dissolved Oxygen (mg/l)	0.1	1,182	8.9	8.8	3.8	11.0	5[1,4]	29	4%
Dissolved Oxygen (% Sat.)	0.1	1,106	87.6	92.1	37.6	114.2	-----	-----	-----
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	353	7.9	7.8	3.8	11.0	5[1,4]	28	8%
Specific Conductance (umhos/cm)	1	1,110	600	596	544	656	-----	-----	-----
pH (S.U.)	0.1	1,110	8.2	8.3	7.3	8.7	7.0[1,4], 9.0[1,3]	0	0%
Turbidity (NTUs)	1	1,108	-----	2	n.d.	62	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	1,110	351	349	207	538	-----	-----	-----
Secchi Depth (in.)	1	25	98	96	33	170	-----	-----	-----
Alkalinity, Total (mg/l)	7	50	152	150	140	170	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	48	3.1	3.1	1.3	5.2	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	50	11	11	n.d.	28	-----	-----	-----
Chloride (mg/l)	1	40	9	10	5	11	100[1,3]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	867	6	4	n.d.	33	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	25	4	4	n.d.	16	-----	-----	-----
Color, True (APHA)	1	10	5	6	3	8	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	50	422	420	276	656	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	50	-----	n.d.	n.d.	0.13	3.1[1,3,5], 1.4[1,5,6]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	50	0.3	0.3	n.d.	1.0	-----	-----	-----
Nitrogen, Nitrate-Nitrite N, Total (mg/l)	0.02	50	-----	0.06	n.d.	0.20	1.0[1,3], 0.25[7]	0	0%
Nitrogen, Total (mg/l)	0.1	50	0.4	0.4	n.d.	1.0	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	50	-----	n.d.	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	50	-----	0.02	n.d.	0.37	0.02[7]	24	48%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	50	-----	n.d.	n.d.	0.05	-----	-----	-----
Sulfate (mg/l)	1	50	154	148	121	180	250[1,3]	0	0%
Suspended Solids, Total (mg/l)	4	50	-----	n.d.	n.d.	55	-----	-----	-----
Microcystin, Total (ug/l)	0.2	25	-----	n.d.	n.d.	0.4	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for Class 1 lakes.
- (2) Applies to hypolimnion of Class 1 lakes during periods of thermal stratification.
- (3) Daily maximum criterion (monitoring results directly comparable to criterion).
- (4) Daily minimum criterion (monitoring results directly comparable to criterion).
- (5) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Nutrient guideline for lake or reservoir improvement or management.

(E) The bottom of the metalimnion is generally defined as the depth where a temperature drop of at least 1.0°C last occurs over a 1-meter depth increment and the top of the hypolimnion is generally defined as the depth where a temperature drop of at least 0.5°C last occurs over a 1-meter depth increment.

Plate 69. Summary of monthly (May through September) water quality conditions monitored in Lake Sakakawea near Beulah Bay (Site GARLK1412DW) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results(A)						Water Quality Standards Attainment		
	Detection Limit(B)	No. of Obs.	Mean(C)	Median	Min.	Max.	State WQS Criteria(D)	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	27	1825.6	1817.8	1807.4	1850.5	-----	-----	-----
Water Temperature (°C)	0.1	1,003	13.8	14.8	4.5	23.3	29.4(1,3)	0	0%
Hypolimnion Water Temperature (°C)(E)	0.1	301	11.3	11.5	6.3	16.6	15.0(2,3)	23	8%
Dissolved Oxygen (mg/l)	0.1	1,003	8.8	8.7	2.8	12.9	5(1,4)	46	5%
Dissolved Oxygen (% Sat.)	0.1	937	87.0	92.1	28.3	116.6	-----	-----	-----
Hypolimnion Dissolved Oxygen (mg/l)(E)	0.1	301	7.8	8.6	2.8	11.0	5(1,4)	41	14%
Specific Conductance (umhos/cm)	1	937	593	598	523	655	-----	-----	-----
pH (S.U.)	0.1	937	8.2	8.2	7.3	8.8	7.0(1,4), 9.0(1,4)	0	0%
Turbidity (NTUs)	1	935	3	1	n.d.	95	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	937	357	358	523	655	-----	-----	-----
Secchi Depth (in.)	1	24	97	105	37	140	-----	-----	-----
Alkalinity, Total (mg/l)	7	50	151	149	130	180	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	48	3.1	3.1	1.2	6.6	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	50	11	11	n.d.	61	-----	-----	-----
Chloride (mg/l)	1	40	9	10	8	11	100(1,3)	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	726	-----	3	n.d.	63	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	25	5	3	n.d.	45	-----	-----	-----
Color, True (APHA)	1	10	6	6	3	7	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	50	409	407	306	598	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	50	-----	n.d.	n.d.	0.14	3.1(1,3,5), 1.4(1,5,6)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	50	0.3	0.3	n.d.	1.1	-----	-----	-----
Nitrogen, Nitrate-Nitrite N, Total (mg/l)	0.02	50	-----	0.05	n.d.	0.20	1.0(1,3), 0.25(7)	0	0%
Nitrogen, Total (mg/l)	0.1	50	0.4	0.4	n.d.	1.3	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	50	-----	n.d.	n.d.	0.03	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	50	-----	0.02	n.d.	0.08	0.02(7)	18	36%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	50	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	50	154	149	134	180	250(1,3)	0	0%
Suspended Solids, Total (mg/l)	4	50	-----	n.d.	n.d.	76	-----	-----	-----
Microcystin, Total (ug/l)	0.2	23	-----	n.d.	n.d.	0.4	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
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- (4) Daily minimum criterion (monitoring results directly comparable to criterion).
- (5) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Nutrient guideline for lake or reservoir improvement or management.

(E) The top of the hypolimnion is generally defined as the depth where a temperature drop of at least 0.5°C last occurs over a 1-meter depth increment.

Plate 70. Summary of monthly (May through September) water quality conditions monitored in Lake Sakakawea near Deepwater Bay (Site GARLK1445DW) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	26	1825.0	1817.6	1807.5	1850.5	-----	-----	-----
Water Temperature (°C)	0.1	752	14.8	15.5	5.5	24.8	29.4(1,3)	0	0%
Hypolimnion Water Temperature (°C)[E]	0.1	205	11.7	12.0	5.5	17.1	15.0(2,3)	24	12%
Dissolved Oxygen (mg/l)	0.1	752	8.4	8.4	1.0	12.4	5(1,4)	44	6%
Dissolved Oxygen (% Sat.)	0.1	704	84.9	89.6	10.0	110.4	-----	-----	-----
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	204	7.4	8.0	1.0	12.2	5(1,4)	26	13%
Specific Conductance (umhos/cm)	1	704	569	573	471	672	-----	-----	-----
pH (S.U.)	0.1	678	8.2	8.2	7.1	8.8	7.0(1,4), 9.0(1,4)	0	0%
Turbidity (NTUs)	1	700	5	2	n.d.	68	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	704	331	333	139	492	-----	-----	-----
Secchi Depth (in.)	1	23	85	76	16	174	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	143	144	89	180	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	46	3.2	3.2	n.d.	5.9	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	48	12	12	n.d.	58	-----	-----	-----
Chloride (mg/l)	1	38	9	9	6	12	100(1,3)	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	542	8	4	n.d.	75	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	24	5	3	n.d.	20	-----	-----	-----
Color, True (APHA)	1	10	6	6	4	12	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	48	398	383	280	602	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	48	-----	n.d.	n.d.	0.08	3.8(1,3,5), 1.6(1,5,6)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	48	0.4	0.3	n.d.	1.5	-----	-----	-----
Nitrogen, Nitrate-Nitrite N, Total (mg/l)	0.02	48	-----	0.4	n.d.	0.23	1.0(1,3), 0.25(7)	0	0%
Nitrogen, Total (mg/l)	0.1	48	0.4	0.4	n.d.	1.6	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	48	-----	n.d.	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	48	-----	0.03	n.d.	0.12	0.02(7)	26	54%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	48	-----	n.d.	n.d.	0.07	-----	-----	-----
Sulfate (mg/l)	1	48	147	145	118	190	250(1,3)	0	0%
Suspended Solids, Total (mg/l)	4	48	-----	n.d.	n.d.	16	-----	-----	-----
Microcystin, Total (ug/l)	0.2	23	-----	n.d.	n.d.	0.2	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for “grab samples” collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for Class 1 lakes.
- (2) Applies to hypolimnion of Class 1 lakes during periods of thermal stratification.
- (3) Daily maximum criterion (monitoring results directly comparable to criterion).
- (4) Daily minimum criterion (monitoring results directly comparable to criterion).
- (5) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Nutrient guideline for lake or reservoir improvement or management.

(E) The top of the hypolimnion is generally defined as the depth where a temperature drop of at least 0.5°C last occurs over a 1-meter depth increment.

Plate 71. Summary of monthly (May through September) water quality conditions monitored in Lake Sakakawea near New Town (Site GARLK1481DW) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results(A)						Water Quality Standards Attainment		
	Detection Limit(B)	No. of Obs.	Mean(C)	Median	Min.	Max.	State WQS Criteria***	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	25	1825.7	1822.3	1807.5	1850.5	-----	-----	-----
Water Temperature (°C)	0.1	450	16.6	17.6	6.9	26.4	29.4(1,3)	0	0%
Hypolimnion Water Temperature (°C)(E)	0.1	57	13.3	12.5	10.9	19.1	15.0(2,3)	11	19%
Dissolved Oxygen (mg/l)	0.1	450	8.3	8.6	3.5	11.3	5(1,4)	27	6%
Dissolved Oxygen (% Sat.)	0.1	440	87.6	92.8	35.8	114.2	-----	-----	-----
Hypolimnion Dissolved Oxygen (mg/l)(E)	0.1	57	5.6	5.3	3.5	7.9	5(1,4)	26	6%
Specific Conductance (umhos/cm)	1	439	519	517	339	723	-----	-----	-----
pH (S.U.)	0.1	440	8.2	8.2	7.3	8.9	7.0(1,4), 9.0(1,4)	0	0%
Turbidity (NTUs)	1	436	23	8	n.d.	296	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	440	315	317	198	455	-----	-----	-----
Secchi Depth (in.)	1	25	44	39	8	124	-----	-----	-----
Alkalinity, Total (mg/l)	7	30	132	131	94	171	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	29	3.1	3.0	1.1	5.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	30	10	10	n.d.	21	-----	-----	-----
Chloride (mg/l)	1	20	8	8	4	13	100(1,3)	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	363	10	8	n.d.	91	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	25	10	8	n.d.	40	-----	-----	-----
Color, True (APHA)	1	10	8	6	4	16			
Dissolved Solids, Total (mg/l)	5	30	366	327	324	588	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	30	-----	n.d.	n.d.	0.30	3.8(1,3,5), 1.4(1,5,6)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	30	0.5	0.3	n.d.	1.7	-----	-----	-----
Nitrogen, Nitrate-Nitrite N, Total (mg/l)	0.02	30	-----	0.05	n.d.	0.30	1.0(1,3), 0.25(7)	0, 2	0%, 7%
Nitrogen, Total (mg/l)	0.1	30	0.5	0.4	0.1	1.8	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	30	-----	0.02	n.d.	0.06	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	30	0.04	0.03	n.d.	0.13	0.02(7)	18	60%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	30	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	30	129	123	74	193	250(1,3)	0	0%
Suspended Solids, Total (mg/l)	4	30	-----	4	n.d.	21	-----	-----	-----
Microcystin, Total (ug/l)	0.2	24	-----	n.d.	n.d.	0.5	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for Class 1 lakes.
- (2) Applies to hypolimnion of Class 1 lakes during periods of thermal stratification.
- (3) Daily maximum criterion (monitoring results directly comparable to criterion).
- (4) Daily minimum criterion (monitoring results directly comparable to criterion).
- (5) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Nutrient guideline for lake or reservoir improvement or management.

(E) The top of the hypolimnion is generally defined as the depth where a temperature drop of at least 0.5°C last occurs over a 1-meter depth increment.

Plate 72. Summary of monthly (May through September) water quality conditions monitored in Lake Sakakawea near White Tail Bay (Site GARLK1512DW) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results(A)						Water Quality Standards Attainment		
	Detection Limit(B)	No. of Obs.	Mean(C)	Median	Min.	Max.	State WQS Criteria***	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	5	1847.3	1848.9	1839.3	1850.5	-----	-----	-----
Water Temperature (°C)	0.1	53	19.0	21.1	11.2	24.5	29.4(1,3)	0	0%
Hypolimnion Water Temperature (°C)(E)	0.1	2	18.1	18.1	17.9	18.2	15.0(2,3)	0	0%
Dissolved Oxygen (mg/l)	0.1	53	8.6	8.3	5.8	11.4	5(1,4)	0	0%
Dissolved Oxygen (% Sat.)	0.1	53	95.9	92.5	63.3	119.0	-----	-----	-----
Hypolimnion Dissolved Oxygen (mg/l)(E)	0.1	2	6.1	6.1	5.8	6.3	5(1,4)	0	0%
Specific Conductance (umhos/cm)	1	53	524	530	420	665	-----	-----	-----
pH (S.U.)	0.1	53	8.2	8.3	7.5	8.7	7.0(1,4), 9.0(1,4)	0	0%
Turbidity (NTUs)	1	52	14	12	2	40	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	53	259	273	197	322	-----	-----	-----
Secchi Depth (in.)	1	4	39	42	20	52	-----	-----	-----
Alkalinity, Total (mg/l)	7	5	134	136	111	154	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	5	3.7	3.7	3.0	4.3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	5	13	13	9	17	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	53	11	9	5	22	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	5	9	7	6	155	-----	-----	-----
Color, True (APHA)	1	5	10	11	7	15			
Dissolved Solids, Total (mg/l)	5	5	322	310	202	470	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	5	-----	0.02	n.d.	0.04	3.1(1,3,5), 1.0(1,5,6)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	5	0.03	0.03	n.d.	0.6	-----	-----	-----
Nitrogen, Nitrate-Nitrite N, Total (mg/l)	0.02	5	-----	0.03	n.d.	0.14	1.0(1,3), 0.25(7)	0	0%
Nitrogen, Total (mg/l)	0.1	5	0.3	0.3	0.1	0.6	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	5	0.03	0.03	n.d.	0.05	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	5	0.04	0.03	0.02	0.06	0.02(7)	4	80%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	5	0.02	0.03	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	5	128	123	92	178	250(1,3)	0	0%
Suspended Solids, Total (mg/l)	4	5	6	6	n.d.	11	-----	-----	-----
Microcystin, Total (ug/l)	0.2	5	-----	n.d.	n.d.	0.2	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for Class 1 lakes.
- (2) Applies to hypolimnion of Class 1 lakes during periods of thermal stratification.
- (3) Daily maximum criterion (monitoring results directly comparable to criterion).
- (4) Daily minimum criterion (monitoring results directly comparable to criterion).
- (5) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Nutrient guideline for lake or reservoir improvement or management.

(E) The top of the hypolimnion is generally defined as the depth where a temperature drop of at least 0.5°C last occurs over a 1-meter depth increment.

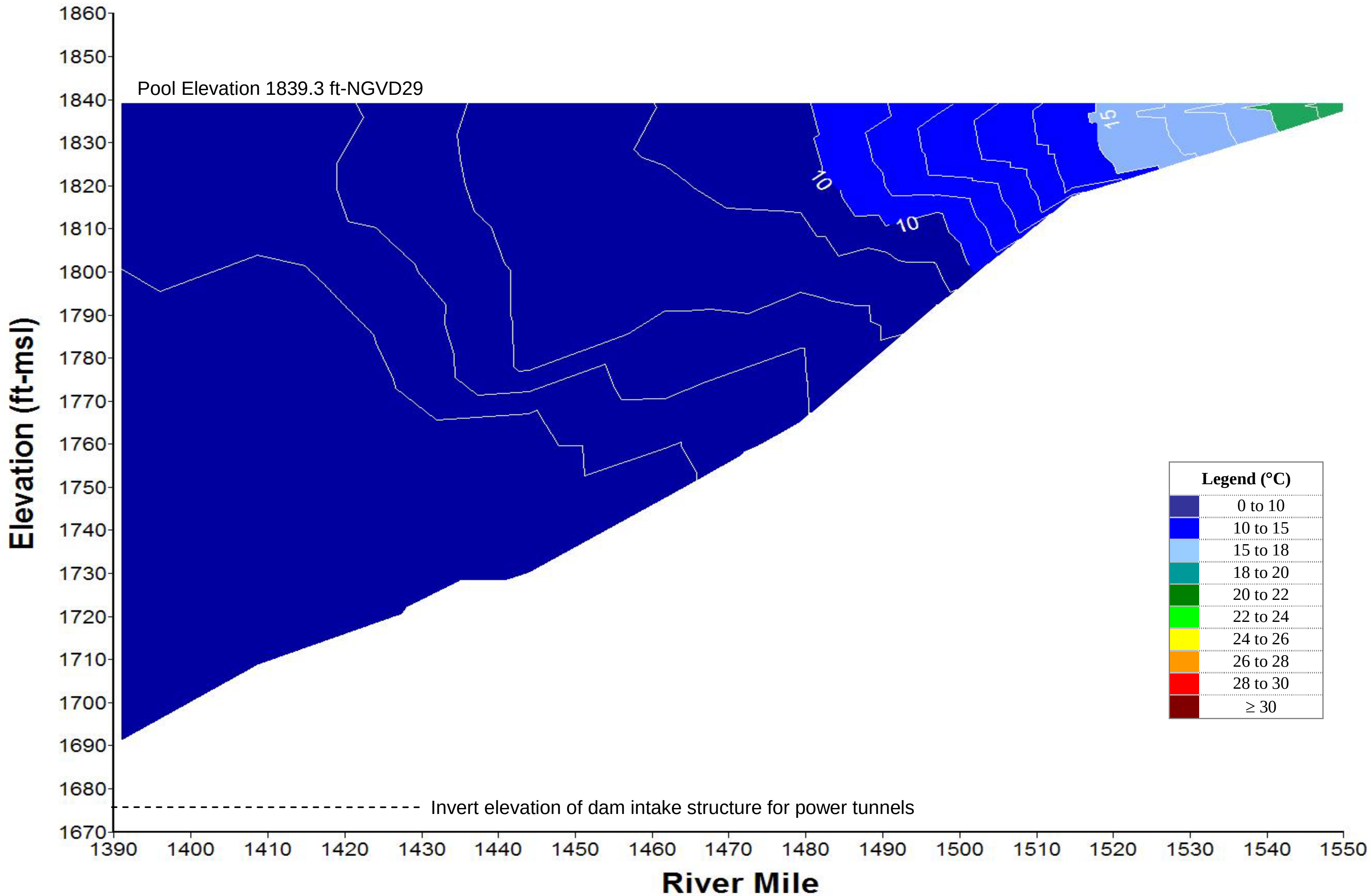

Plate 73. Longitudinal water temperature (°C) contour plot of Lake Sakakawea based on depth-profile water temperatures measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, GARLK1512DW, and GARNFMORRR1 on May 18, 2010.

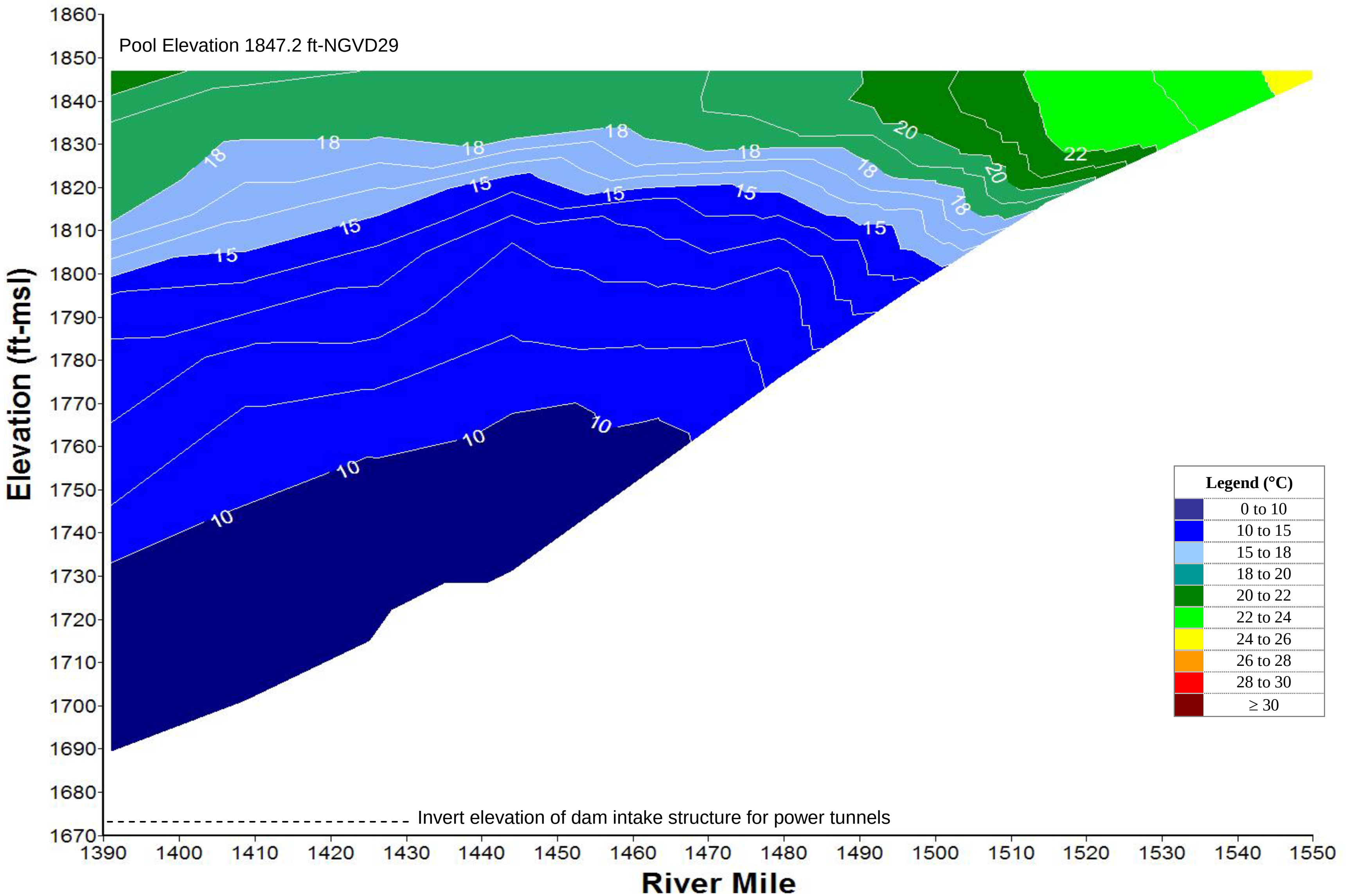

Plate 74. Longitudinal water temperature (°C) contour plot of Lake Sakakawea based on depth-profile water temperatures measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, GARLK1512DW, and GARNFMORRR1 on June 28, 2010.

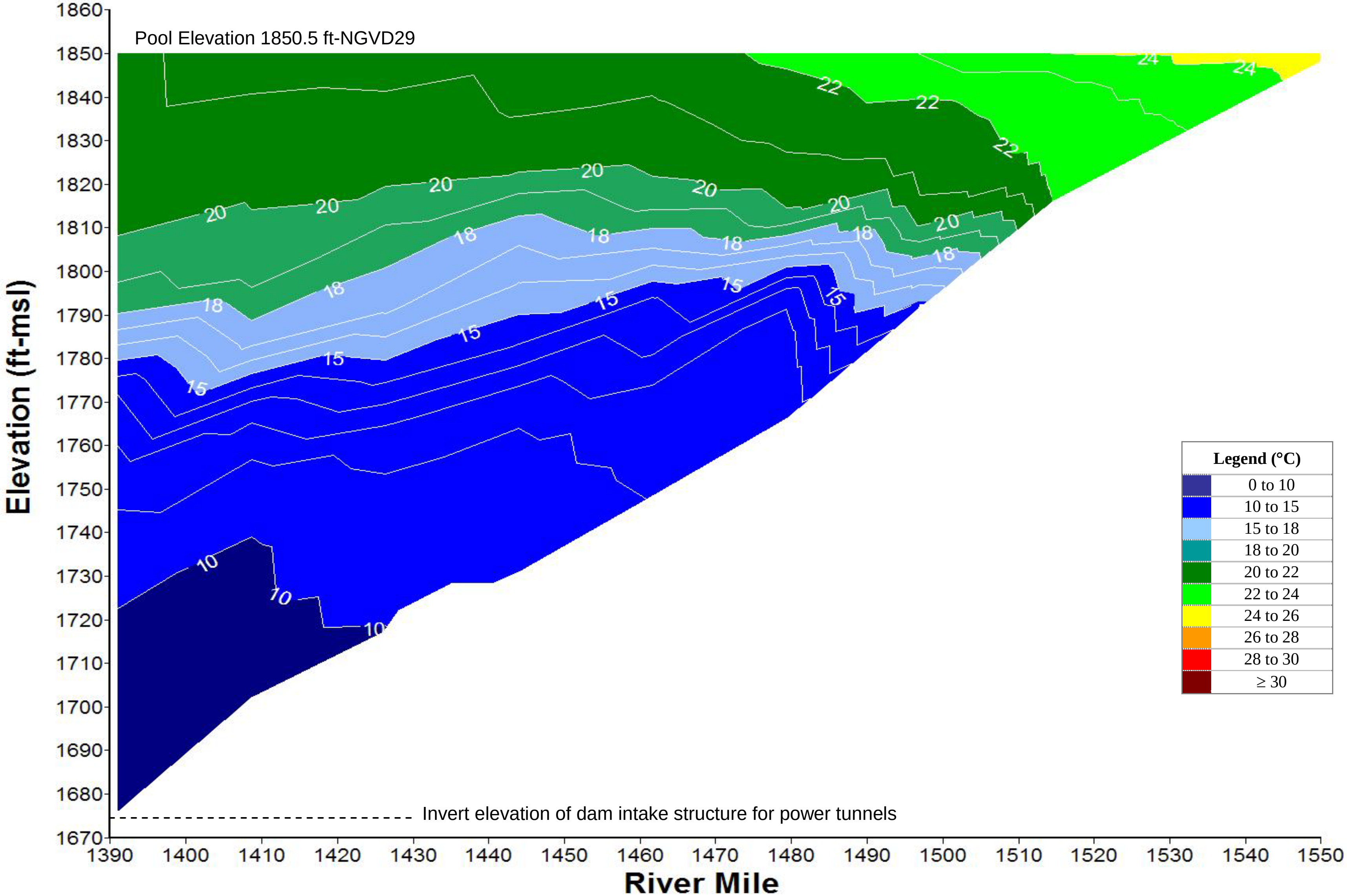

Plate 75. Longitudinal water temperature (°C) contour plot of Lake Sakakawea based on depth-profile water temperatures measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, GARLK1512DW, and GARNFMORRR1 on July 20, 2010.

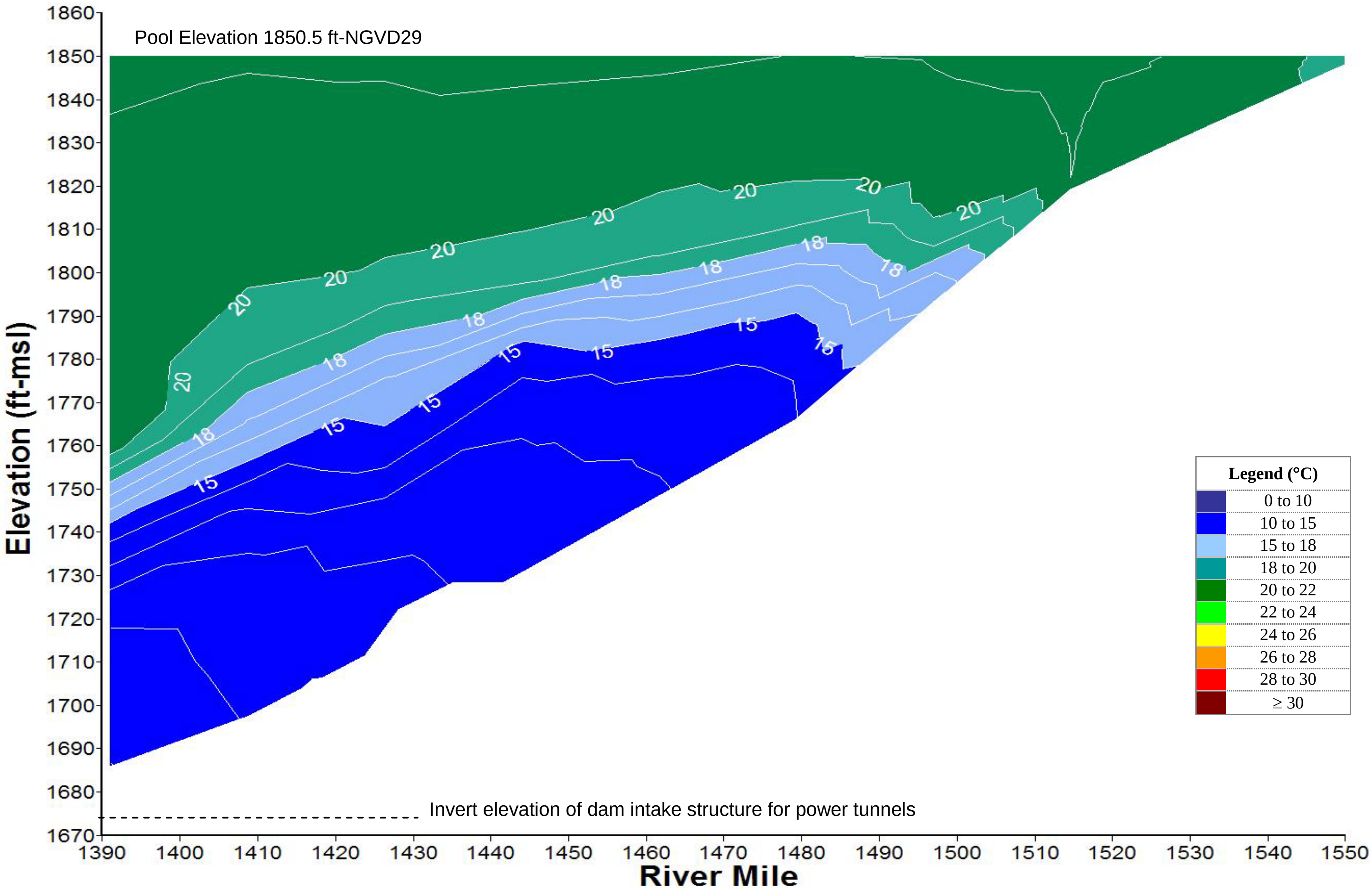

Plate 76. Longitudinal water temperature (°C) contour plot of Lake Sakakawea based on depth-profile water temperatures measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, GARLK1512DW, and GARNFMORRR1 on August 25, 2010.

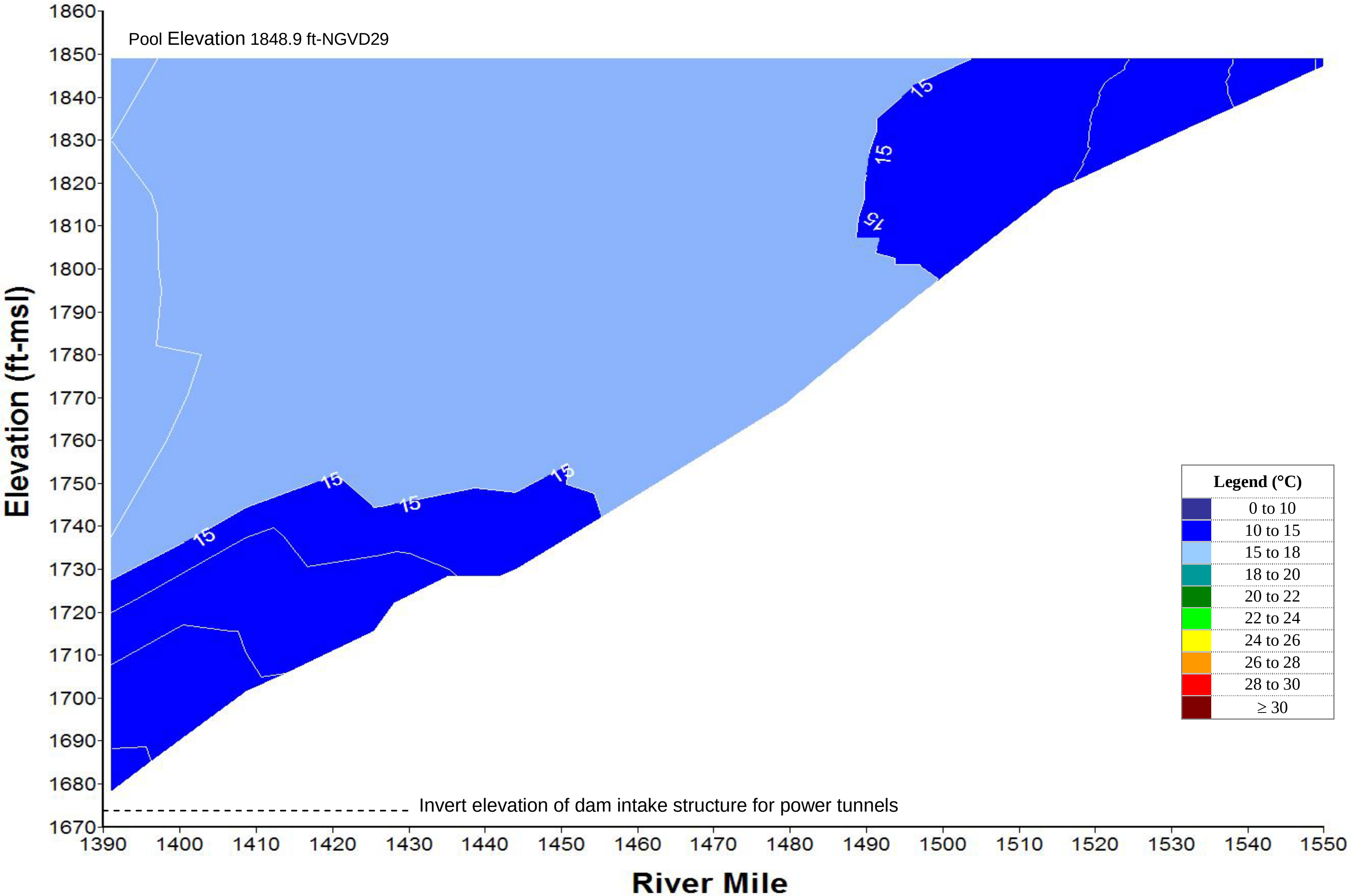

Plate 77. Longitudinal water temperature (°C) contour plot of Lake Sakakawea based on depth-profile water temperatures measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, GARLK1512DW, and GARNFMORRR1 on September 21, 2010.

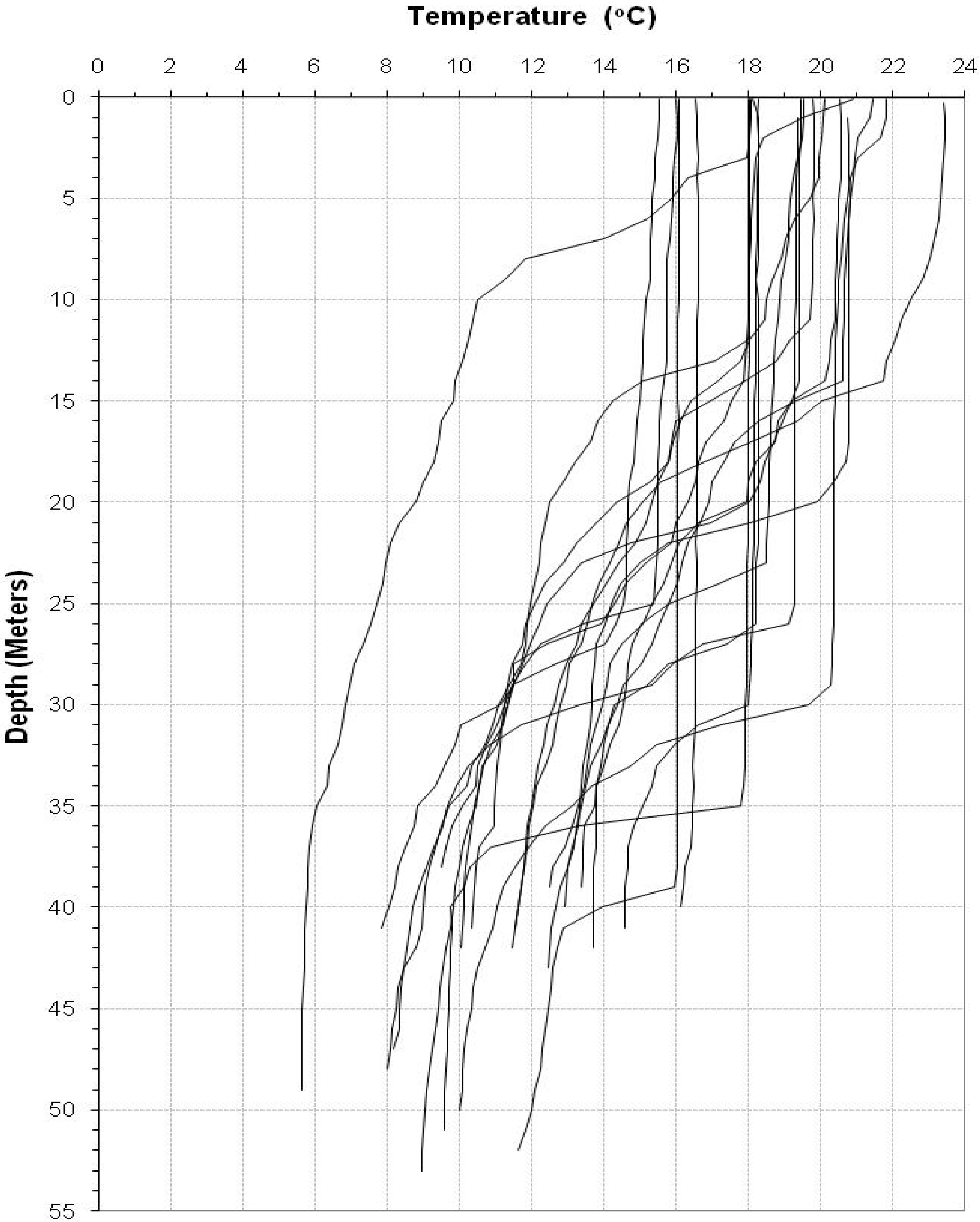

Plate 78. Temperature depth profiles for Lake Sakakawea generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., GARLK1390A) during the summer months over the 5-year period of 2006 to 2010.

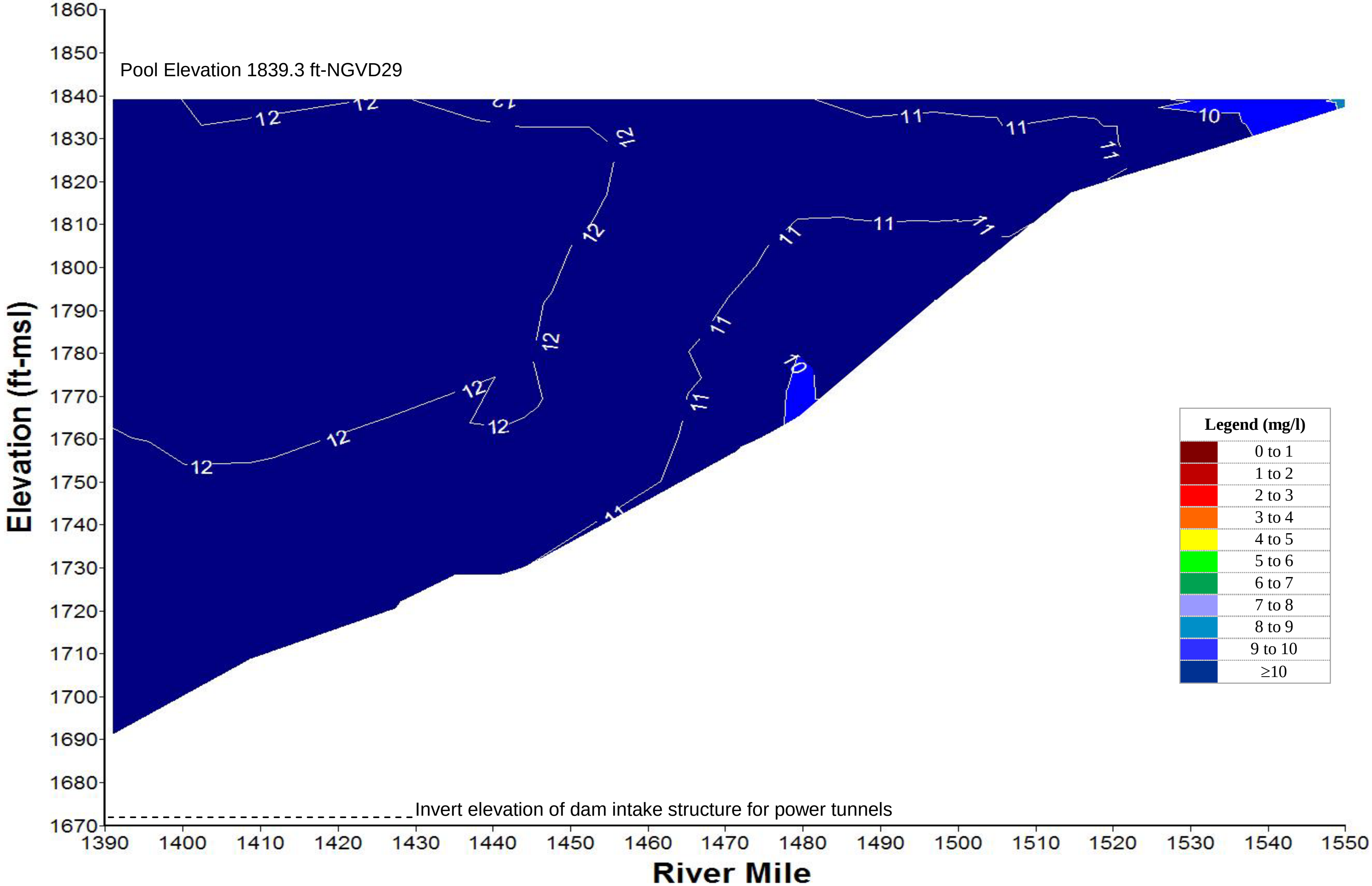

Plate 79. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Sakakawea based on depth-profile dissolved oxygen concentrations measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, GARLK1512DW, and GARNFMORRR1 on May 18, 2010.

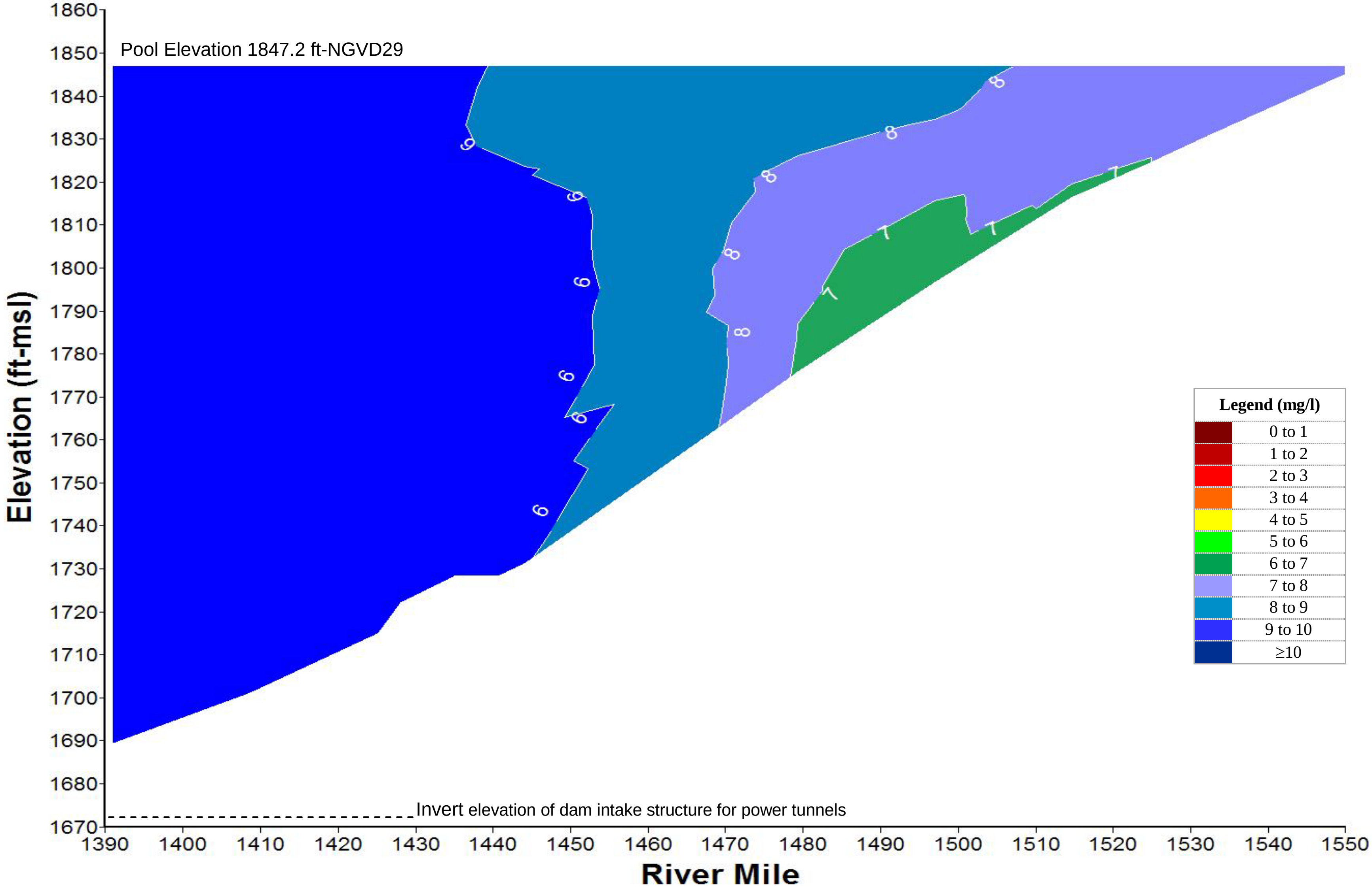

Plate 80. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Sakakawea based on depth-profile dissolved oxygen concentrations s measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, GARLK1512DW, and GARNFMORRR1 on June 28, 2010.

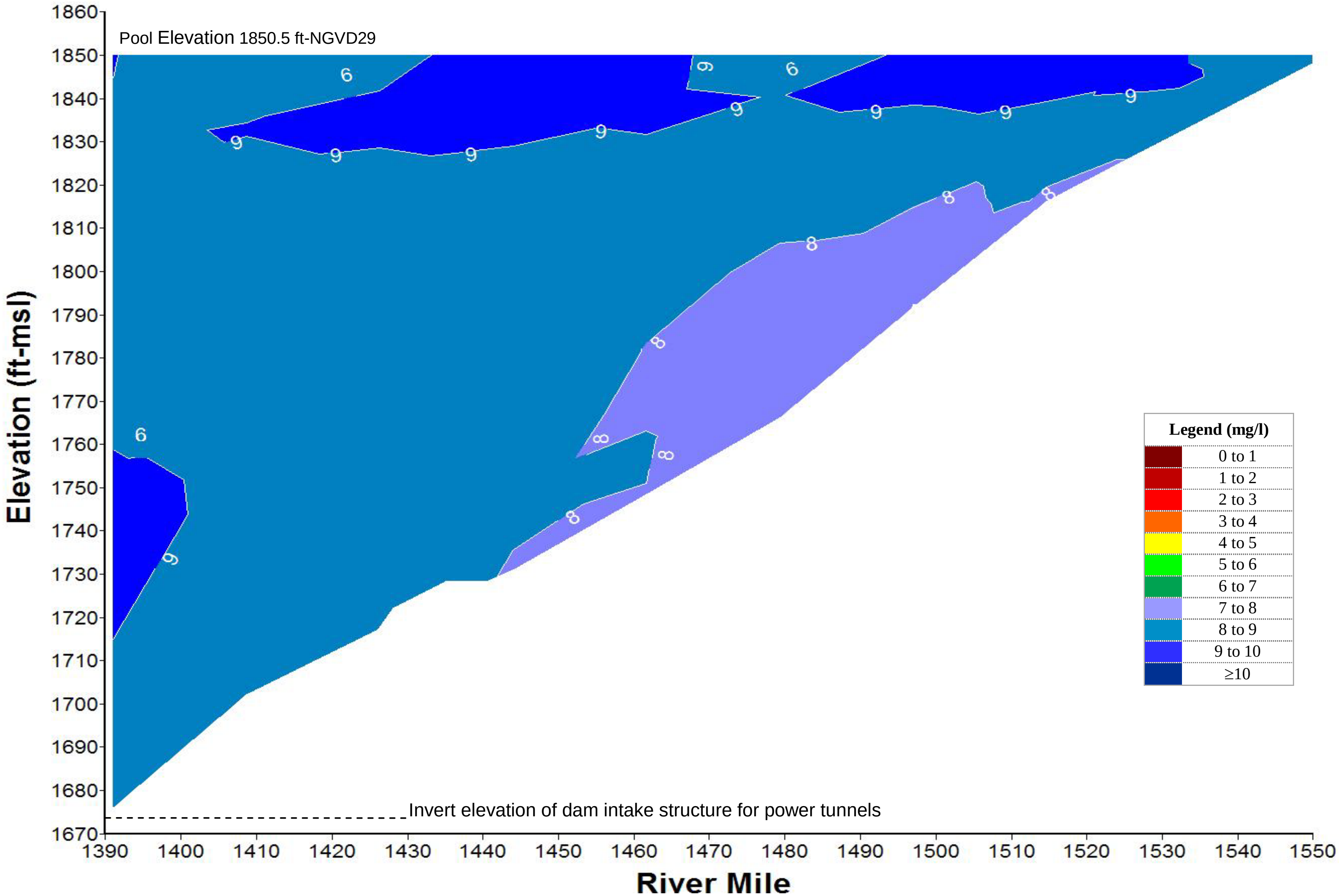

Plate 81. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Sakakawea based on depth-profile dissolved oxygen concentrations measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, GARLK1512DW, and GARNFMORRR1 on July 20, 2010.

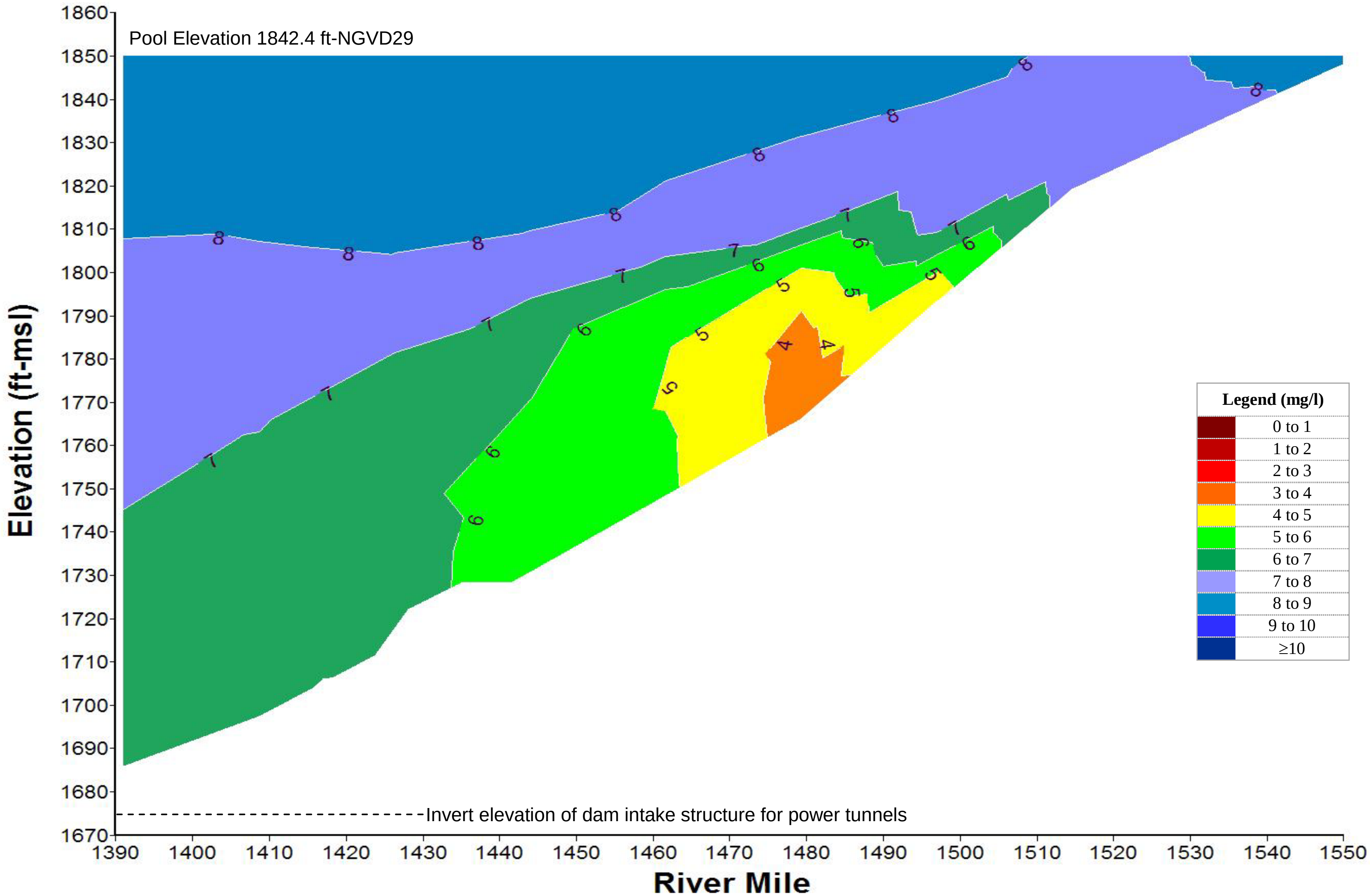

Plate 82. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Sakakawea based on depth-profile dissolved oxygen concentrations measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, GARLK1512DW, and GARNFMORRR1 on August 25, 2010.

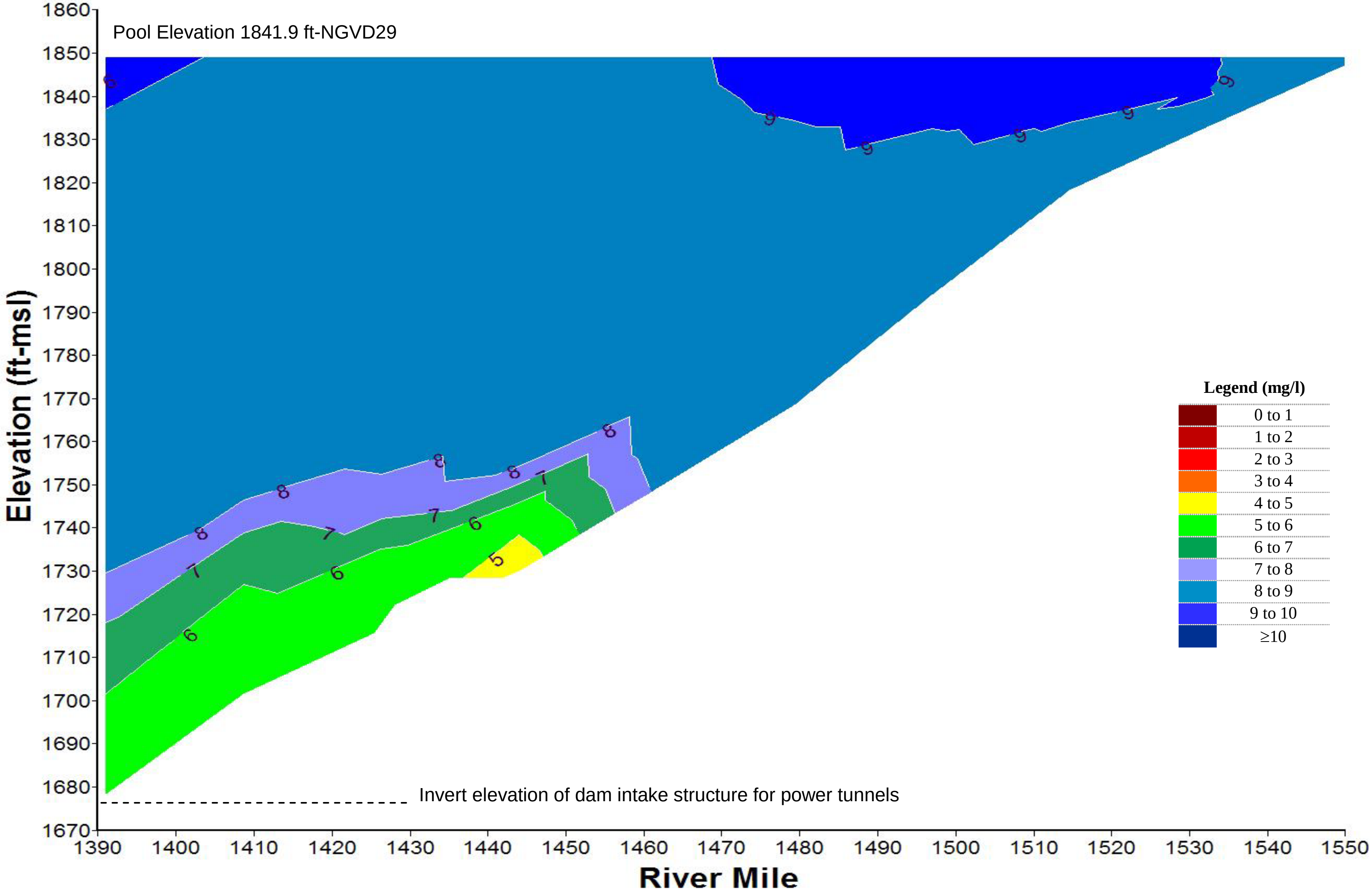

Plate 83. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Sakakawea based on depth-profile dissolved oxygen concentrations measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, GARLK1512DW, and GARNFMORRR1 on September 21, 2010.

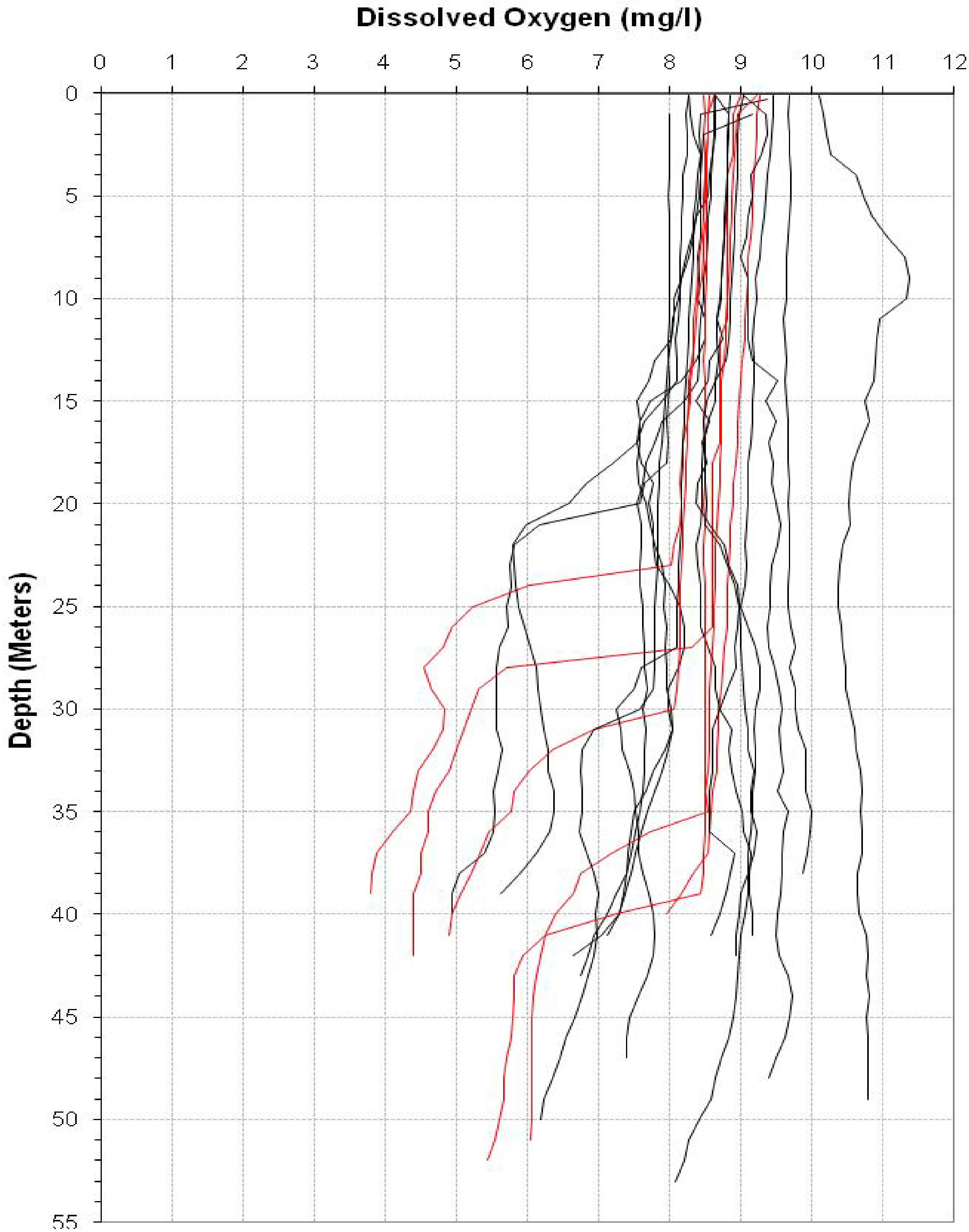

Plate 84. Dissolved oxygen depth profiles for Lake Sakakawea generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., GARLK1390A) during the summer over the 5-year period of 2006 through 2010.
(Note: Red profile plots were measured in the month of September.)

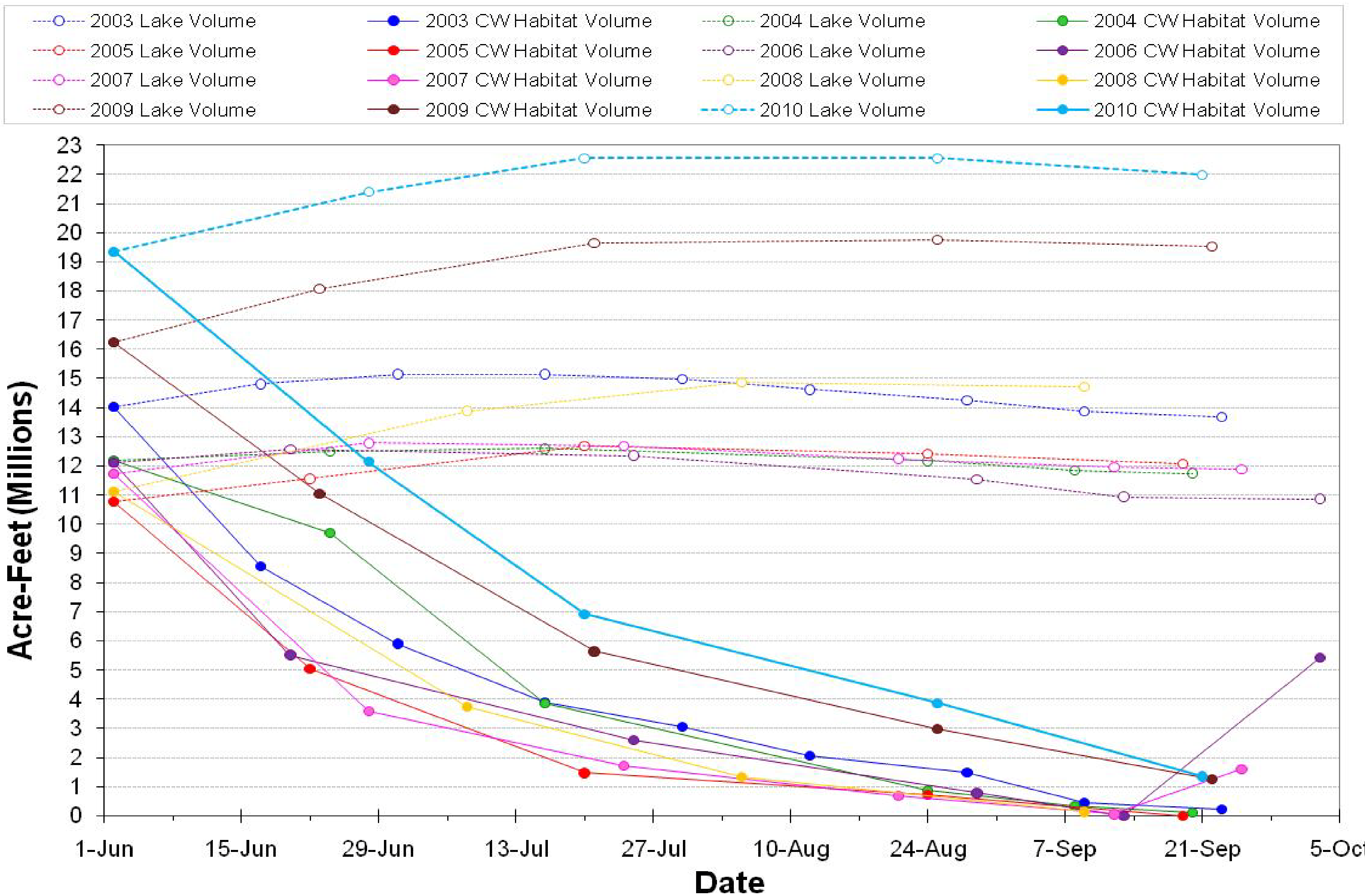

Plate 85. Estimated volume of coldwater fishery habitat in Lake Sakakawea during 2003, 2004, 2005, 2006, 2007, 2008, 2009, and 2010.

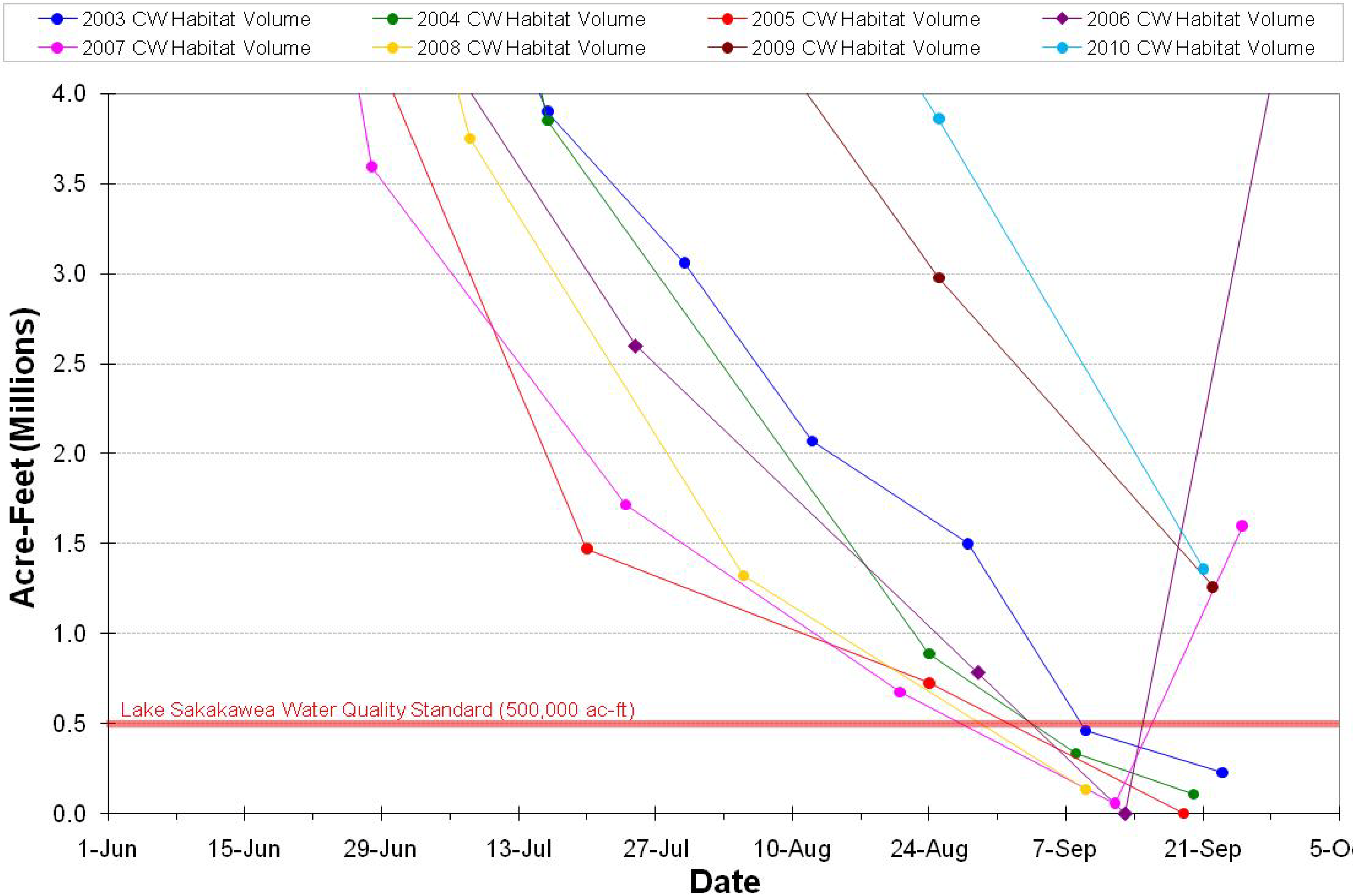

Plate 86. Estimated volume of coldwater fishery habitat in Lake Sakakawea during 2003, 2004, 2005, 2006, 2007, 2008, 2009, and 2010. Y-axis scaled to better discern estimated volumes near 500,000 ac-ft water quality standard defined by North Dakota for Lake Sakakawea.

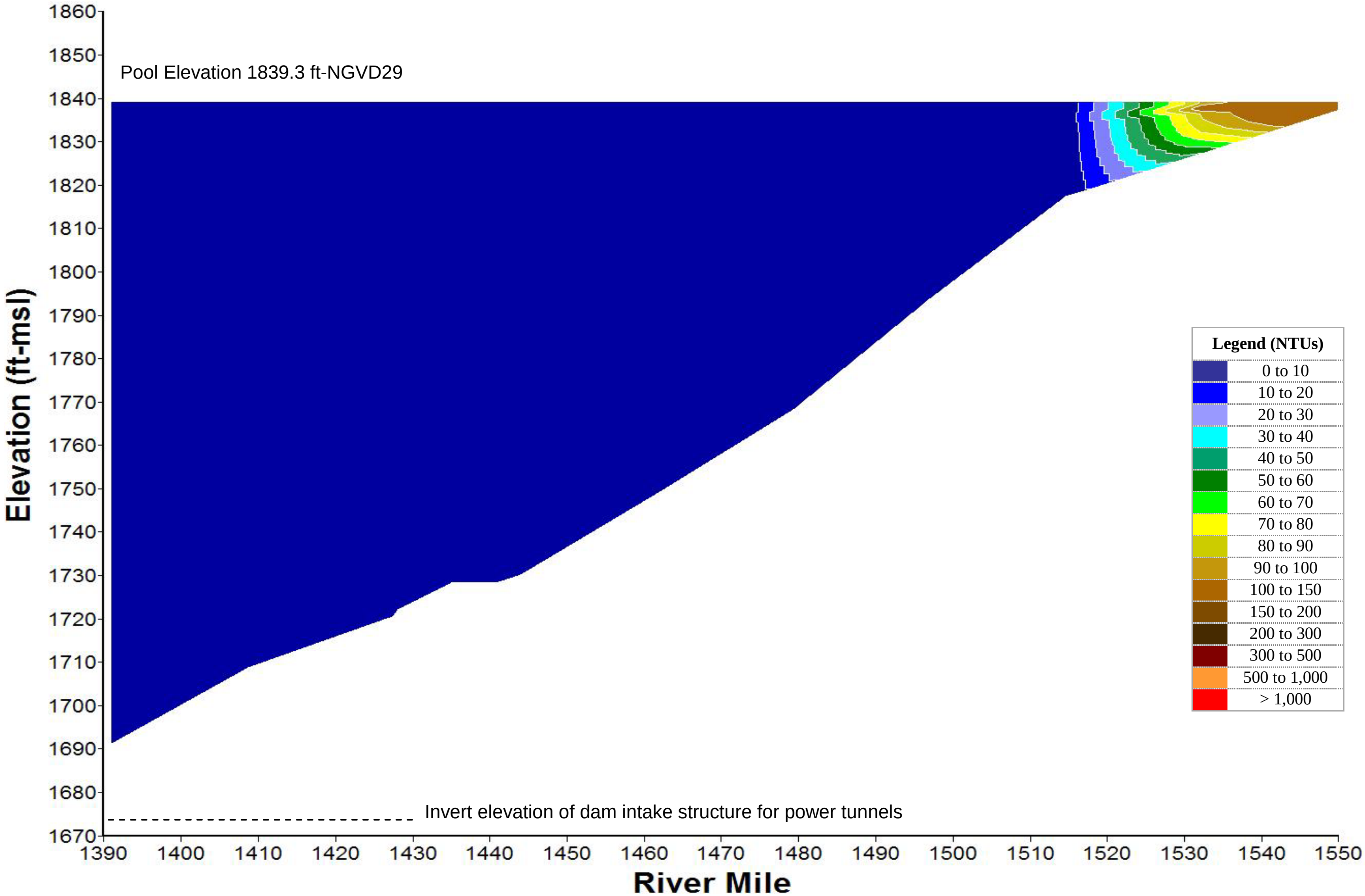

Plate 87. Longitudinal turbidity (NTU) contour plot of Lake Sakakawea based on depth-profile turbidity levels monitored at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, GARLK1512DW, and GARNFMORRR1 on May 18, 2010.

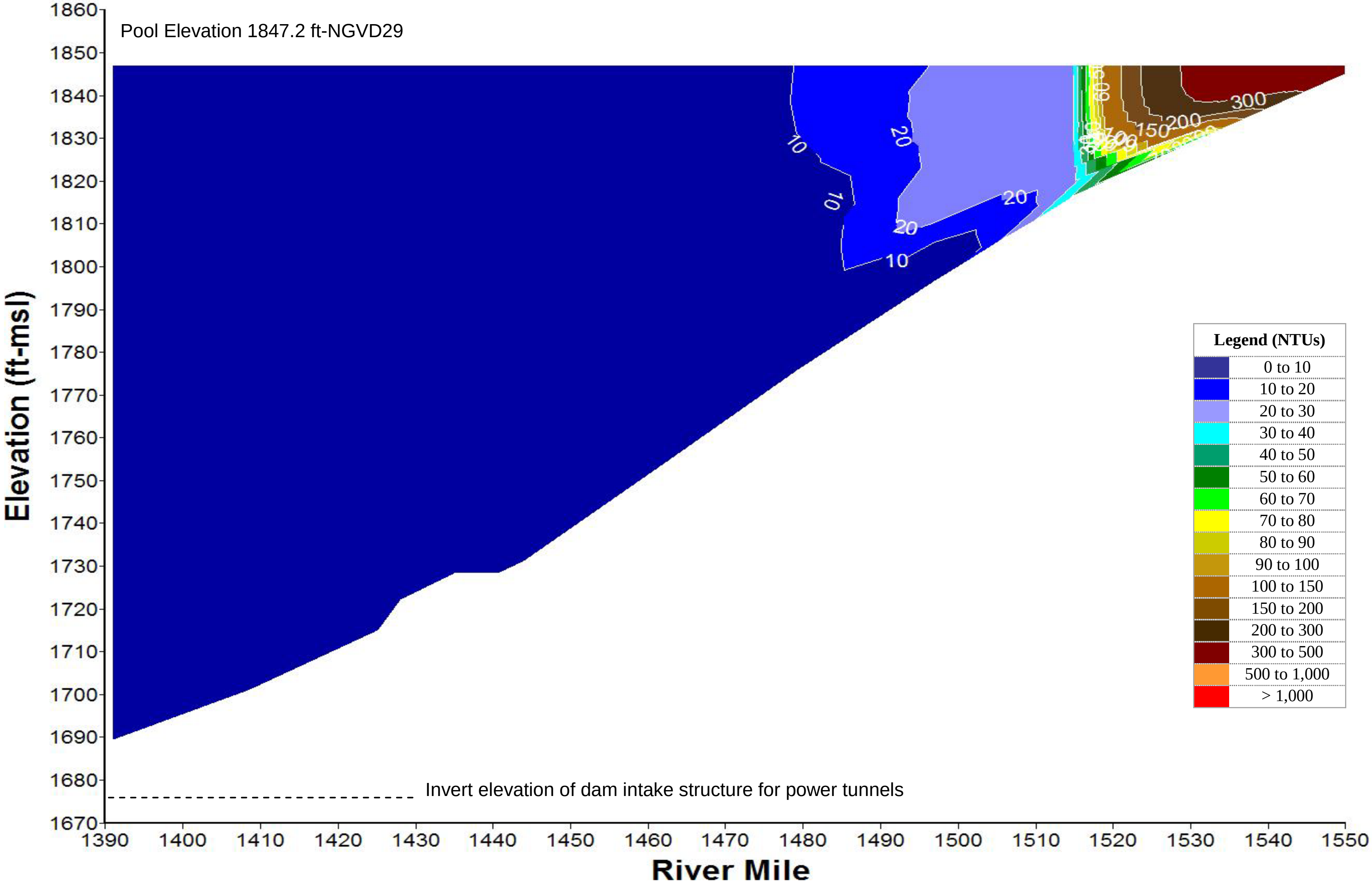

Plate 88. Longitudinal turbidity (NTU) contour plot of Lake Sakakawea based on depth-profile turbidity levels monitored at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on June 28, 2010**.**

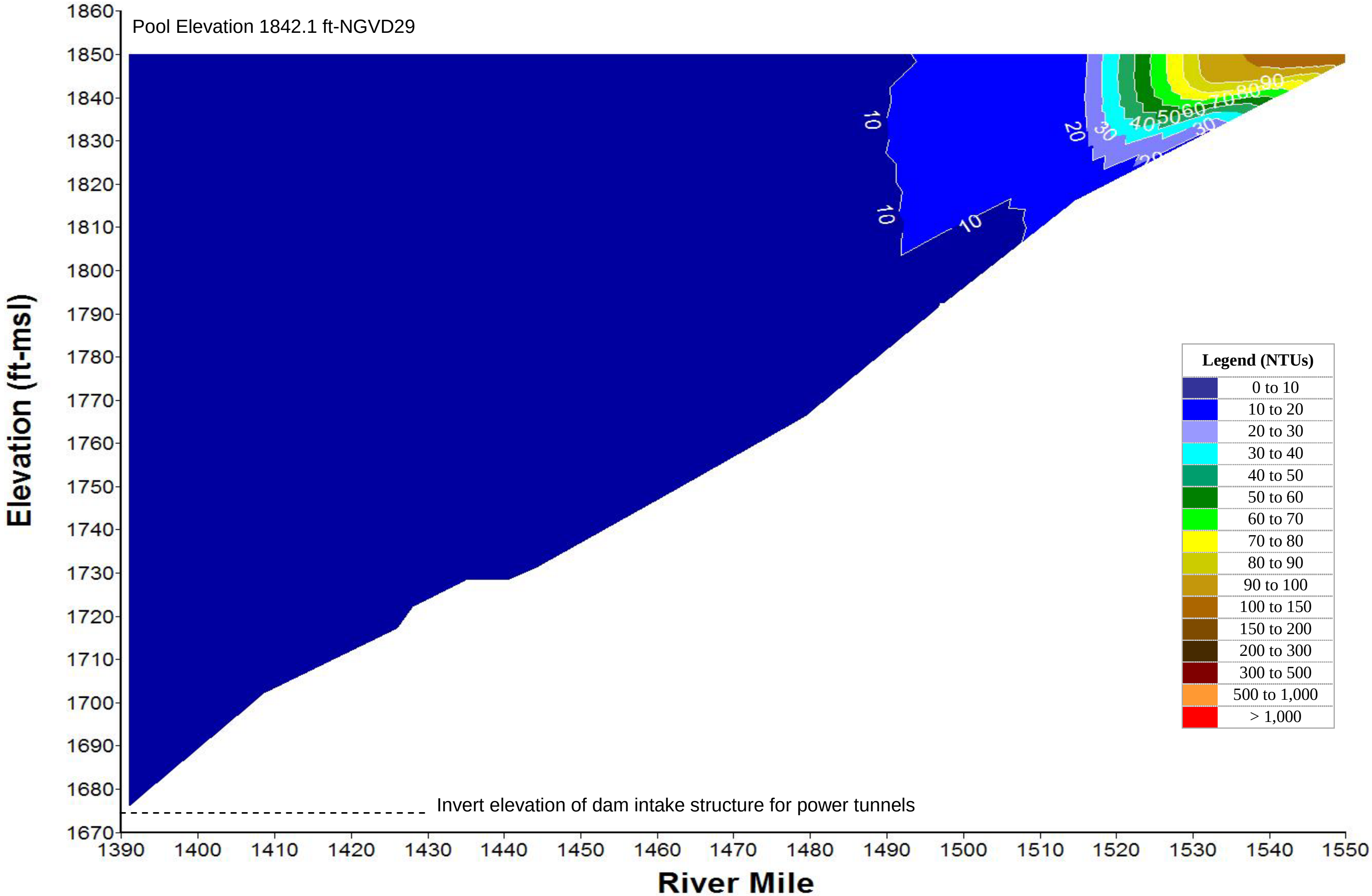

Plate 89. Longitudinal turbidity (NTU) contour plot of Lake Sakakawea based on depth-profile turbidity levels monitored at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, GARLK1512DW, and GARNFMORRR1 on July 20, 2010**.**

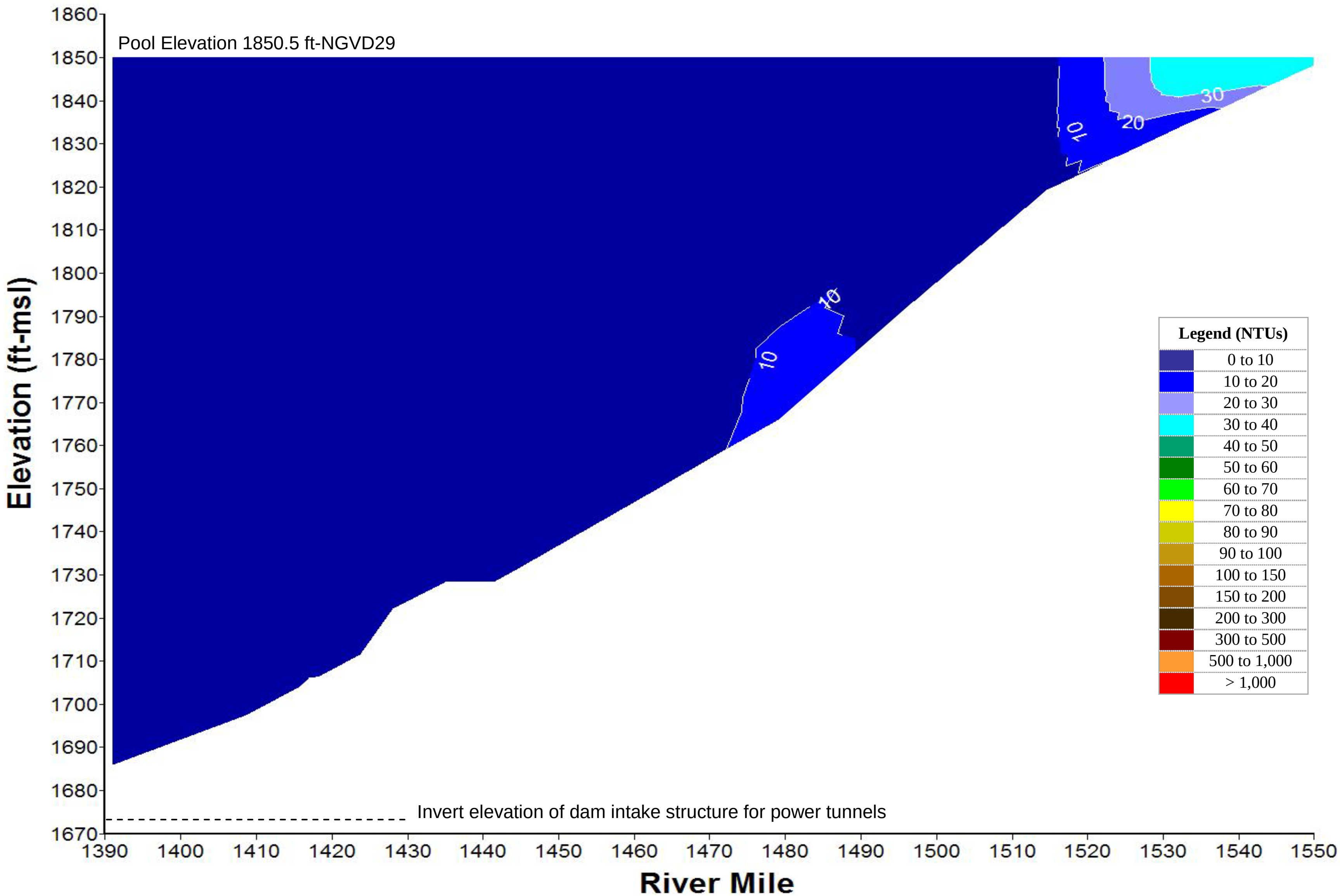

Plate 90. Longitudinal turbidity (NTU) contour plot of Lake Sakakawea based on depth-profile turbidity levels monitored at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, GARLK1512DW, and GARNFMORRR1 on August 25, 2010**.**

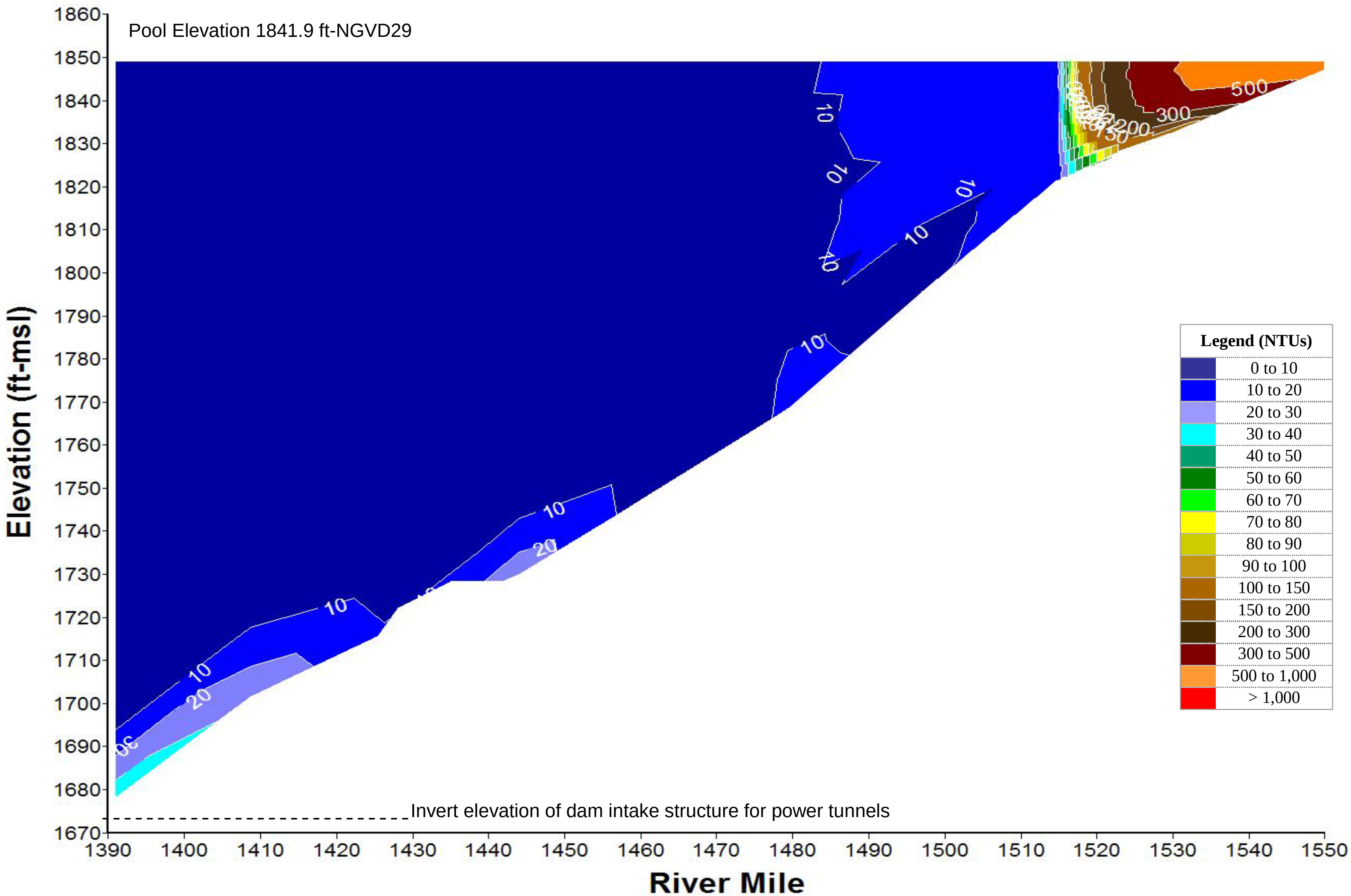

Plate 91. Longitudinal turbidity (NTU) contour plot of Lake Sakakawea based on depth-profile turbidity levels monitored at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, GARLK1512DW, and GARNFMORRR1 on September 22, 2009**.**

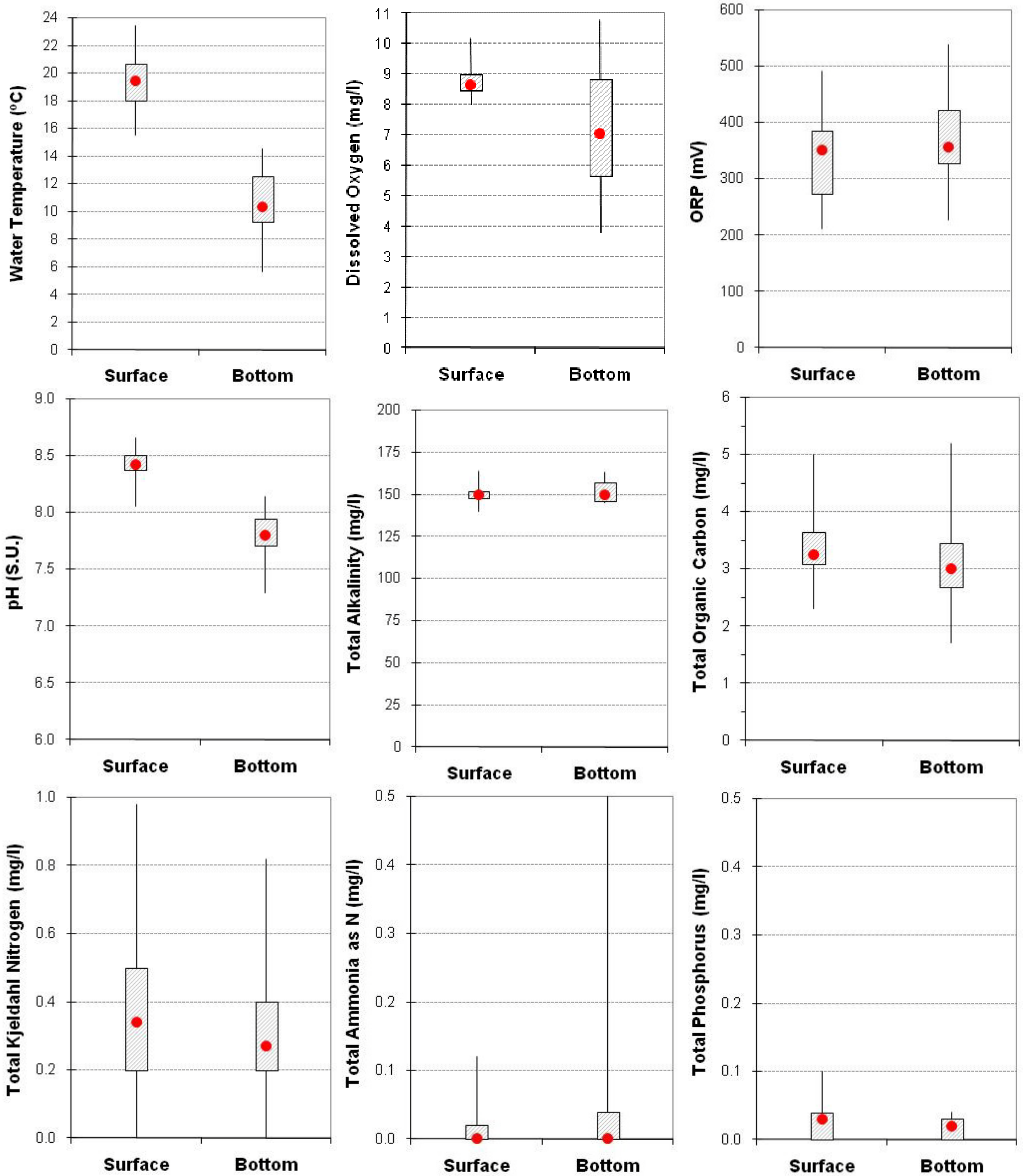

Plate 92. Box plots comparing paired surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus measurements taken in Lake Sakakawea at site GARLK1390A during the summer months of the 5-year period 2006 through 2010.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 93. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Sakakawea at site GARLK1390A during the 5-year period 2006 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
May 2006	0.0613	2	0.36	5	0.45	0	-----	1	0.16	1	0.02	0	-----	0	-----
Jun 2006	0.1492	3	0.99	2	<0.01	0	<0.01	1	0.01	1	<0.01	0	-----	0	-----
Jul 2006	0.2333	4	0.95	3	0.01	0	-----	1	0.03	0	-----	0	-----	1	<0.01
Aug 2006	0.4609	5	0.54	3	0.14	1	0.01	1	0.11	1	0.01	1	0.16	1	0.03
Oct 2006	0.0619	6	0.82	2	0.09	0	-----	1	0.09	0	-----	0	-----	1	<0.01
May 2007	0.0959	7	0.82	2	0.05	1	0.05	1	0.03	0	-----	1	0.05	0	-----
June 2007	0.1160	7	0.85	2	0.08	2	0.03	1	0.04	0	-----	1	<0.01	0	-----
July 2007	1.1572	9	0.54	9	0.21	0	-----	1	0.21	0	-----	1	0.04	0	-----
Aug 2007	1.6791	5	0.40	8	0.05	1	0.17	1	0.06	2	<0.01	2	0.32	0	-----
Sep 2007	0.0003	9	0.34	6	0.18	0	-----	1	0.07	3	0.01	2	0.42	0	-----
May 2008	0.0124	6	1.00	1	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	0	-----
Jun 2008	0.1964	10	1.00	0	-----	1	<0.01	1	<0.01	1	<0.01	0	-----	0	-----
Jul 2008	0.4123	5	0.99	2	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	0	-----
Aug 2008	0.2874	2	0.07	1	0.14	1	0.33	1	0.23	2	0.01	1	0.22	0	-----
Sep 2008	0.1455	5	0.94	4	0.01	0	-----	1	0.05	1	<0.01	0	-----	0	-----
May 2009	1.7822	5	0.13	2	0.69	1	<0.01	2	0.17	1	<0.01	1	0.01	0	-----
Jun 2009	6.4878	6	0.77	2	0.04	2	0.12	2	0.06	1	<0.01	0	-----	1	<0.01
Jul 2009	0.0613	5	0.64	5	0.15	1	0.03	1	0.12	1	0.05	1	0.01	0	-----
Aug 2009	0.1492	7	0.87	4	0.01	0	-----	1	0.03	4	0.06	1	0.03	1	<0.01
Sep 2009	0.2333	7	0.06	4	0.01	0	-----	2	0.03	4	0.90	0	-----	0	-----
May 2010	0.7779	7	0.96	1	<0.01	2	<0.01	2	0.03	0	-----	0	-----	0	-----
Jul 2010	0.2488	6	0.84	9	0.04	1	0.01	2	0.08	2	<0.01	1	0.03	1	0.01
Sep 2010	0.1822	8	0.92	5	0.02	0	-----	2	0.03	5	0.01	1	0.02	0	-----
Mean*	**0.6518**	**5.9**	**0.69**	**3.6**	**0.11**	**0.7**	**0.05**	**1.3**	**0.07**	**1.3**	**0.07**	**0.6**	**0.11**	**0.3**	**0.01**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 94. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Sakakawea at site GARLK1412DW during the 5-year period 2006 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
May 2006	0.2173	6	1.00	1	<0.01	0	-----	1	<0.01	1	<0.01	0	-----	0	-----
Jun 2006	0.0938	3	0.76	7	0.05	0	-----	1	0.14	0	-----	1	<0.01	1	0.05
Jul 2006	0.3978	6	0.87	4	0.02	2	0.01	1	0.07	2	<0.01	2	0.03	0	-----
Aug 2006	0.1231	2	0.61	6	0.07	0	-----	1	0.14	1	0.01	2	<0.01	1	0.17
Oct 2006	0.5774	8	0.88	1	<0.01	0	-----	1	0.01	2	0.06	3	0.04	0	-----
May 2007	0.1119	11	0.69	3	0.17	1	0.06	1	0.08	0	-----	0	-----	0	-----
June 2007	0.1191	8	0.65	5	0.13	2	0.15	1	0.07	0	-----	0	-----	0	-----
July 2007	0.2045	6	0.72	6	0.07	1	0.03	1	0.09	2	0.01	1	0.07	0	-----
Aug 2007	0.1573	6	0.26	7	0.17	2	0.01	1	0.10	3	0.01	1	0.46	0	-----
Sep 2007	0.2296	7	0.54	5	0.06	1	<0.01	2	0.03	5	0.02	1	0.35	0	-----
May 2008	0.7578	6	1.00	1	<0.01	1	<0.01	1	<0.01	1	<0.01	1	<0.01	0	-----
Jun 2008	0.7383	9	0.99	0	-----	2	<0.01	0	<0.01	0	<0.01	0	-----	0	-----
Jul 2008	0.0001	3	0.19	6	0.16	2	0.03	1	0.56	0	-----	2	0.06	0	-----
Aug 2008	0.0530	5	0.69	4	0.01	2	0.13	1	0.16	0	-----	3	0.01	0	-----
Sep 2008	0.2504	6	0.93	2	0.01	0	-----	1	0.05	1	<0.01	2	0.01	0	-----
May 2009	0.4624	2	0.42	3	0.45	0	-----	2	0.12	1	<0.01	2	0.01	1	<0.01
Jun 2009	0.0433	6	0.74	4	0.05	2	<0.01	1	0.04	1	0.15	0	-----	1	<0.01
Jul 2009	0.2491	7	0.66	5	0.08	1	0.06	1	0.14	3	0.01	0	-----	1	0.05
Aug 2009	0.2717	11	0.53	8	0.13	1	<0.01	1	0.23	4	0.09	2	0.02	0	-----
Sep 2009	0.6807	7	0.36	6	0.11	1	<0.01	2	0.51	4	0.02	1	<0.01	1	<0.01
May 2010	0.9452	6	0.99	1	<0.01	1	<0.01	1	0.01	0	-----	0	-----	0	-----
July 2010	0.0444	7	0.42	9	0.10	1	<0.01	2	0.26	5	0.06	3	0.15	0	-----
Sep 2010	0.1970	6	0.91	7	0.04	0	-----	1	0.04	3	0.01	1	<0.01	0	-----
Mean*	**0.3011**	**6.3**	**0.69**	**4.4**	**0.09**	**1.0**	**0.03**	**1.1**	**0.12**	**1.7**	**0.03**	**1.2**	**0.08**	**0.3**	**0.05**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 95. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Sakakawea at site GARLK1445DW during the 5-year period 2006 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
May 2006	0.4943	7	0.99	1	<0.01	0	-----	2	<0.01	1	<0.01	0	-----	0	-----
Jun 2006	0.0493	8	0.73	5	0.08	1	0.02	1	0.17	0	-----	0	-----	0	-----
Jul 2006	0.2715	3	0.73	5	0.01	1	<0.01	1	0.22	3	0.03	1	<0.01	0	-----
Aug 2006	0.2523	4	0.81	4	0.05	0	-----	1	0.07	1	0.05	1	0.02	0	-----
Oct 2006	0.3603	7	0.51	12	0.36	0	-----	1	0.04	6	0.08	1	0.01	0	-----
May 2007	4.4349	12	0.98	5	0.02	0	-----	1	<0.01	0	-----	0	-----	0	-----
June 2007	0.1608	8	0.73	9	0.19	0	-----	2	0.05	0	-----	1	0.02	0	-----
July 2007	0.3059	7	0.80	7	0.04	1	0.04	1	0.05	3	0.05	1	0.03	0	-----
Aug 2007	0.2153	6	0.34	8	0.16	0	-----	1	0.15	3	<0.01	1	0.33	1	0.01
Sep 2007	0.2538	8	0.80	10	0.06	0	-----	1	0.02	4	0.01	1	0.12	0	-----
May 2008	0.5216	13	0.90	2	<0.01	0	-----	1	0.10	0	-----	0	-----	0	-----
Jun 2008	1.1114	9	1.00	4	<0.01	0	-----	1	<0.01	0	-----	0	-----	0	-----
Jul 2008	0.0001	8	0.63	4	0.07	0	0.01	1	0.29	0	-----	0	-----	0	-----
Aug 2008	0.6281	6	0.94	3	<0.01	0	-----	1	0.06	2	<0.01	0	-----	0	-----
Sep 2008	0.0379	3	0.34	4	0.13	0	-----	1	0.21	2	0.33	0	-----	0	-----
May 2009	1.2829	6	0.92	3	0.04	1	<0.01	1	0.04	1	<0.01	1	<0.01	0	-----
Jun 2009	0.0878	8	0.32	3	0.16	2	0.02	1	0.49	1	<0.01	0	-----	0	-----
Aug 2009	0.3755	9	0.31	8	0.25	0	-----	1	0.19	7	0.24	1	<0.01	0	-----
Sep 2009	0.6144	6	0.76	6	0.10	0	-----	2	0.11	4	0.03	0	-----	0	-----
May 2010	0.3566	9	0.99	2	<0.01	0	-----	2	0.01	0	-----	0	-----	0	-----
Jul 2010	0.2984	4	0.86	8	0.02	2	0.01	2	0.02	7	0.09	1	0.01	0	-----
Sep 2010	0.1460	6	0.84	2	0.02	0	-----	1	0.04	2	0.07	1	0.02	0	-----
Mean*	**0.5572**	**7.1**	**0.74**	**5.2**	**0.08**	**0.4**	**0.01**	**1.2**	**0.11**	**2.1**	**0.07**	**0.5**	**0.05**	**0.0**	**0.01**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 96. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Sakakawea at site GARLK1481DW during the 5-year period 2006 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
May 2006	0.3500	10	0.90	9	0.03	2	0.01	1	<0.01	1	<0.01	2	0.04	3	0.01
Jun 2006	0.2715	8	0.96	4	0.02	0	-----	1	<0.01	1	0.01	0	-----	1	<0.01
Jul 2006	0.1099	7	0.29	7	0.11	1	0.02	1	0.49	3	0.05	1	0.03	0	-----
Aug 2006	0.2267	8	0.36	13	0.25	1	0.01	1	0.06	3	0.26	2	0.05	3	0.02
Oct 2006	1.3950	10	0.78	17	0.05	2	0.03	2	0.01	6	0.12	2	0.01	2	0.01
May 2007	2.9999	11	0.89	7	0.11	0	-----	1	0.01	0	-----	0	-----	0	-----
June 2007	0.5131	10	0.87	7	0.10	0	-----	1	0.02	1	<0.01	0	-----	0	-----
July 2007	0.2544	9	0.13	6	0.11	1	<0.01	1	0.13	4	0.62	1	0.02	0	-----
Aug 2007	0.2229	8	0.33	8	0.16	1	<0.01	1	0.15	5	0.03	1	0.32	2	0.01
Sep 2007	0.9186	10	0.82	12	0.04	1	0.01	2	0.01	4	0.06	2	0.04	2	0.02
May 2008	1.4193	12	0.99	2	<0.01	1	0.01	1	<0.01	1	<0.01	0	-----	1	<0.01
Jun 2008	0.3575	10	1.00	1	<0.01	0	-----	1	<0.01	0	-----	0	-----	0	<0.01
Jul 2008	0.0002	7	0.90	3	<0.01	0	-----	1	0.08	0	-----	1	<0.01	1	0.01
Aug 2008	0.8564	7	0.87	7	0.08	2	<0.01	1	0.03	4	<0.01	2	0.01	2	<0.01
Sep 2008	1.2785	5	0.95	6	0.02	1	<0.01	1	0.02	5	0.01	1	<0.01	1	<0.01
May 2009	1.7601	12	0.87	4	0.02	1	<0.01	2	0.11	2	<0.01	1	<0.01	0	-----
Jun 2009	4.1205	12	0.61	4	0.28	2	<0.01	1	0.10	3	0.01	1	<0.01	0	-----
Jul 2009	1.7387	9	0.80	7	0.04	1	<0.01	1	0.08	3	<0.01	2	<0.01	0	-----
Aug 2009	3.3832	8	0.32	7	0.02	2	<0.01	2	0.10	2	<0.01	1	0.56	0	-----
Sep 2009	1.3606	12	0.68	8	0.02	1	<0.01	2	0.27	5	0.03	1	<0.01	0	-----
May 2010	1.5741	9	0.97	3	<0.01	0	-----	2	0.03	0	-----	2	<0.01	2	<0.01
Jul 2010	0.3619	6	0.80	3	0.10	0	-----	2	0.07	2	0.03	0	-----	0	-----
Sep 2010	0.7547	7	0.91	7	0.02	0	-----	2	0.01	5	0.05	0	-----	2	<0.01
Mean*	**1.1403**	**9.0**	**0.74**	**6.6**	**0.07**	**0.9**	**0.01**	**1.3**	**0.08**	**2.6**	**0.07**	**1.0**	**0.07**	**1.0**	**0.01**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 97. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Sakakawea at site GARLK1512DW during 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
May 2010	0.1409	8	0.72	14	0.21	1	0.07	0	-----	1	<0.01	0	-----	1	0.01
Jul 2010	1.4346	4	0.93	5	0.02	1	<0.01	2	0.03	6	0.02	2	<0.01	0	-----
Sep 2010	0.3120	4	0.21	6	0.08	1	0.01	2	0.05	5	0.60	1	0.05	1	0.01
Mean*	**0.6292**	**5.3**	**0.62**	**8.3**	**0.10**	**1.0**	**0.03**	**1.3**	**0.04**	**4.0**	**0.21**	**1.0**	**0.03**	**0.7**	**0.01**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 98. Estimated biomass, number of species, and percent composition (based on biomass) by taxonomic grouping for zooplankton tow samples collected in Lake Sakakawea at Sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARLK1512DW during 2010.

Date	Estimated Biomass (μg/L dry wt.)	Cladocerans		Copepods		Rotifers	
		No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.
Site GARLK1930A – Near Dam							
May 2010	3.53	0	-----	4	0.89	6	0.11
July 2010	23.38	4	0.71	5	0.28	6	<0.01
Sept 2010	11.78	4	0.78	4	0.19	4	0.03
Mean	**12.90**	**2.7**	**0.75**	**4.3**	**0.45**	**5.3**	**0.05**
Site GARLK1412DW – Beulah Bay							
May 2010	7.36	1	0.07	4	0.89	4	0.03
July 2010	48.88	5	0.69	4	0.31	2	<0.01
Sept 2010	11.10	4	0.65	5	0.35	5	0.01
Mean	**22.45**	**3.3**	**0.47**	**4.3**	**0.52**	**3.7**	**0.01**
Site GARLK1445DW – Deepwater Bay							
May 2010	7.54	0	-----	3	0.54	7	0.46
July 2010	18.32	3	0.60	4	0.40	7	<0.01
Sept 2010	17.62	4	0.67	4	0.31	9	0.03
Mean	**14.49**	**2.3**	**0.64**	**3.7**	**0.42**	**7.7**	**0.16**
Site GARLK1481DW – New Town							
May 2010	7.01	0	-----	1	0.20	11	0.80
July 2010	81.49	1	0.92	6	0.08	4	<0.01
Sept 2010	24.95	5	0.30	5	0.66	6	0.05
Mean	**37.82**	**2.0**	**0.61**	**4.0**	**0.31**	**7.0**	**0.28**
Site GARLK1512DW – White Tail Bay							
May 2010	2.33	0	-----	1	0.18	14	0.82
July 2010	111.82	3	0.90	3	0.09	8	0.01
Sept 2010	565.45	3	0.85	6	0.15	9	<0.01
Mean	**226.53**	**2.0**	**0.88**	**3.3**	**0.14**	**10.3**	**0.28**

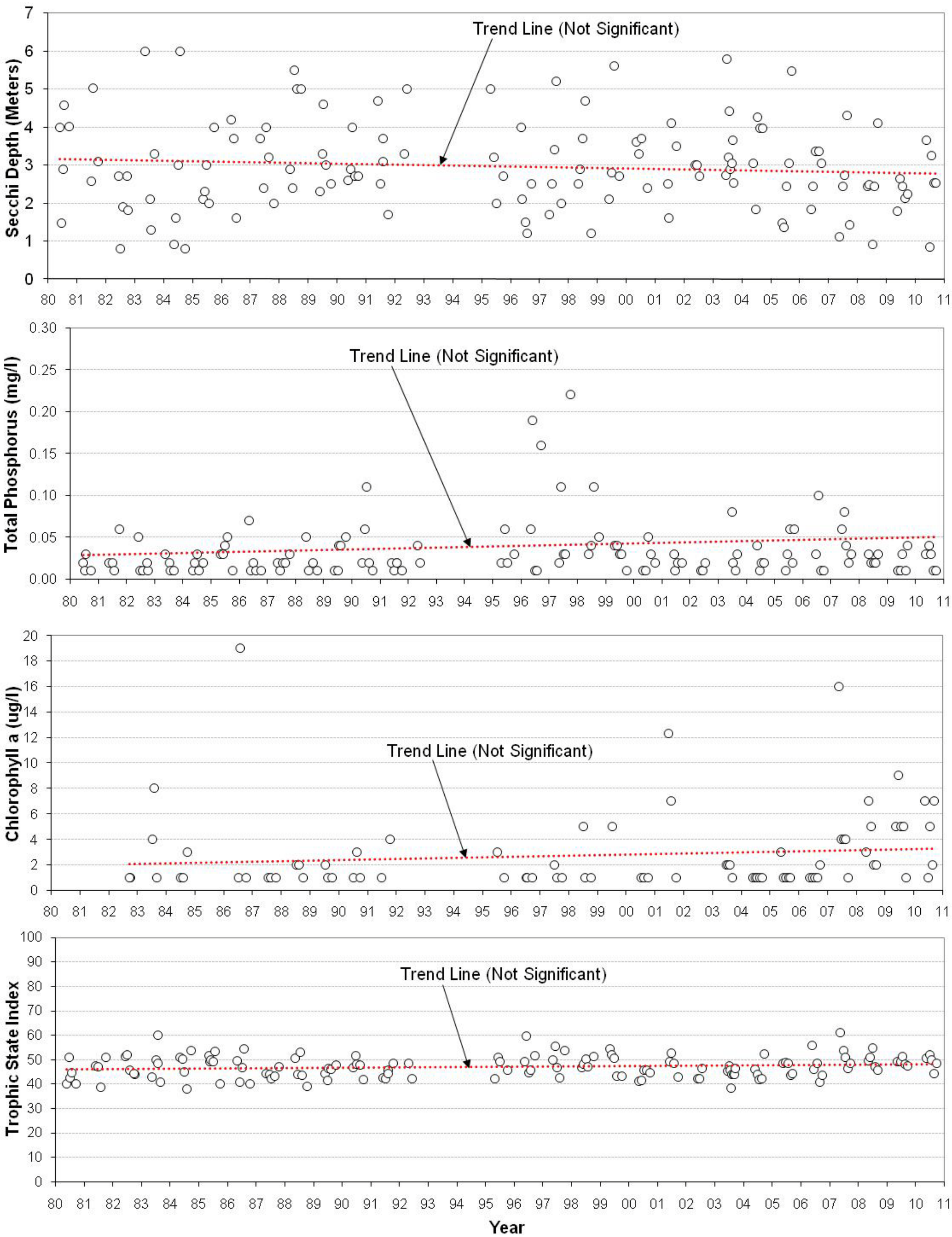

Plate 99. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Lake Sakakawea at the near-dam, ambient site (i.e., site GARLK1390A) over the 31-year period of 1980 through 2010.

Plate 100. Summary of monthly (April through September) near-surface water quality conditions monitored in the Missouri River near Williston, North Dakota at monitoring site GARNFMORRR1 during the 5-year period 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	29	20,392	14,530	7,649	52,320	-----	-----	-----
Water Temperature (°C)	0.1	28	19.0	19.8	8.4	30.9	29.4(1,2)	1	4%
Dissolved Oxygen (mg/l)	0.1	28	8.7	8.5	6.8	10.7	5(1,3)	0	0%
Dissolved Oxygen (% Sat.)	0.1	28	96.8	96.4	78.1	105.1	-----	-----	-----
pH (S.U.)	0.1	28	8.3	8.4	7.9	9.0	7.0(1,3), 9.0(1,2)	0	0%
Specific Conductance (umhos/cm)	1	28	557	571	292	784	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	28	318	310	189	409	-----	-----	-----
Turbidity (NTU)	1	28	250	113	6	1,211	-----	-----	-----
Alkalinity, Total (mg/l)	7	29	142	150	90	181	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	28	3.2	2.9	1.5	8.2	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	29	18	14	3	93	-----	-----	-----
Chloride, Dissolved (mg/l)	1	23	9	9	4	17	100(1,2)	0	0%
Chlorophyll a (ug/l)	1	5	4	4	n.d.	9	-----	-----	-----
Color (APHA)	1	9	9	8	3	14	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	29	413	387	214	818	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	29	-----	0.02	n.d.	0.21	3.9 (1,2,4), 0.84 (1,4,5)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	29	0.8	0.6	0.1	2.1	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	29	-----	0.02	n.d.	0.30	1.0(1,2)	0	0%
Nitrogen, Total (mg/l)	0.1	29	0.8	0.6	0.2	2.1	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	28	-----	0.02	n.d.	0.15	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	29	0.28	0.17	0.04	1.10	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	29	-----	n.d.	n.d.	0.05	-----	-----	-----
Sulfate (mg/l)	1	29	140	144	64	222	250(1,2)	0	0%
Suspended Solids, Total (mg/l)	4	29	328	166	37	2,156	-----	-----	-----
Suspended Sediment, Total (mg/l)	4	6(D)	354	226	58	1,086	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for Class 1 streams.
- (2) Daily maximum criterion (monitoring results directly comparable to criterion).
- (3) Daily minimum criterion (monitoring results directly comparable to criterion).
- (4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (5) 30-day average criterion (monitoring results not directly comparable to criterion).

(D) Suspended sediment analyses are for samples collected only in 2010.

Plate 101. Summary of annual near-surface metals and pesticide levels monitored in the Missouri River near Williston, North Dakota at monitoring site GARNFMORRR1 during the 5-year period 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	4	-----	n.d.	n.d.	50	-----	-----	-----
Aluminum, Total (ug/l)	25	4	4,565	3,781	2,710	7,990	750[6]	4	100%
Antimony, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Antimony, Total (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	5.6[8]	0	0%
Arsenic, Dissolved (ug/l)	1	4	3	3	2	3	-----	-----	-----
Arsenic, Total (ug/l)	1	4	4	4	3	6	340[1], 150[2], 10[3]	0	0%
Barium, Dissolved (ug/l)	5	4	49	50	44	53	-----	-----	-----
Barium, Total (ug/l)	5	4	74	77	50	90	1,000[8]	0	0%
Beryllium, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Beryllium, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	4[8]	0	0%
Cadmium, Dissolved (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Cadmium, Total (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	4.4[6], 0.46[7], 5[8]	0	0%
Calcium, Dissolved (mg/l)	0.01	5	49	47	46	55	-----	-----	-----
Chromium, Dissolved (ug/l)	10	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Chromium, Total (ug/l)	10	4	-----	n.d.	n.d.	n.d.	3,245[6], 155[7], 100[8]	0	0%
Copper, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	3	-----	-----	-----
Copper, Total (ug/l)	2	4	-----	n.d.	n.d.	4	28[6], 17[7], 1,000[8]	0	0%
Hardness, Total (mg/l)	0.4	5	206	205	181	231	-----	-----	-----
Iron, Dissolved (ug/l)	40	7	31	40	n.d.	50	-----	-----	-----
Iron, Total (ug/l)	40	9	6,551	6,137	2,016	17,712	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	6.6	-----	-----	-----
Lead, Total (ug/l)	0.5	4	4.2	3.5	3.0	6.6	203[6], 7.9[7], 15[8]	0	0%
Magnesium, Dissolved (mg/l)	0.01	5	20	21	16	23	-----	-----	-----
Manganese, Dissolved (ug/l)	2	10	-----	4	n.d.	30	-----	-----	-----
Manganese, Total (ug/l)	2	9	167	139	42	421	-----	-----	-----
Mercury, Dissolved (ug/l)	0.02	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Mercury, Total (ug/l)	0.02	5	-----	n.d.	n.d.	n.d.	1.7[6], 0.012[7], 0.05[8]	0, b.d., 0	0%
Nickel, Dissolved (ug/l)	10	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Nickel, Total (ug/l)	10	4	-----	n.d.	n.d.	10	861[6], 96[7], 100[8]	0	0%
Selenium, Total (ug/l)	1	3	-----	1	n.d.	1	20[6], 5[7], 50[8]	0	0%
Silver, Dissolved (ug/l)	1	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Silver, Total (ug/l)	1	4	-----	n.d.	n.d.	n.d.	14[6]	0	0%
Sodium, Dissolved (mg/l)	0.01	1	46	46	46	46	-----	-----	-----
Thallium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Total (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	0.24[7]	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Zinc, Total (ug/l)	10	4	-----	17	n.d.	80	220[6,7], 7,400[8]	0	0%
Pesticide Scan (ug/l)[D]	0.05[E]	4	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

[A] Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for Class 1 streams.
- [2] Daily maximum criterion (monitoring results directly comparable to criterion).
- [3] Daily minimum criterion (monitoring results directly comparable to criterion).
- [4] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- [5] 30-day average criterion (monitoring results not directly comparable to criterion).
- [6] Acute criterion for aquatic life.
- [7] Chronic criterion for aquatic life.
- [8] Human health criterion for surface waters.

Note: Some of North Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

[E] Detection limits vary by pesticide – 0.05 ug/l is a median detection limit for the pesticides in the pesticide scan.

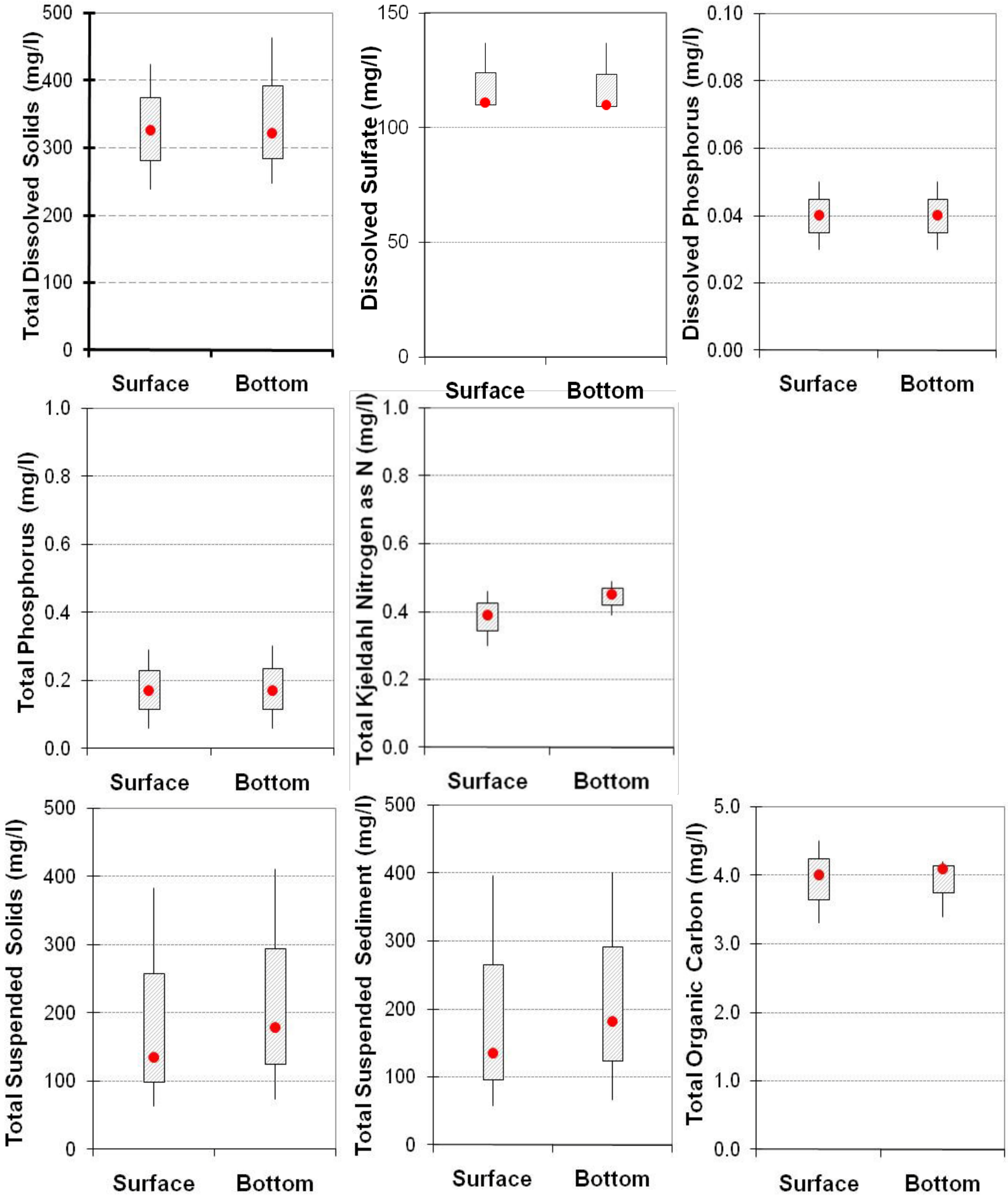

Plate 102. Box plots comparing paired surface and bottom total dissolved solids, dissolved sulfate, dissolved phosphorus, total phosphorus, total Kjeldahl nitrogen, total suspended solids, total suspended sediment, and total organic carbon measurements taken in the Missouri River at site GARNFMORR1 during 2010. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

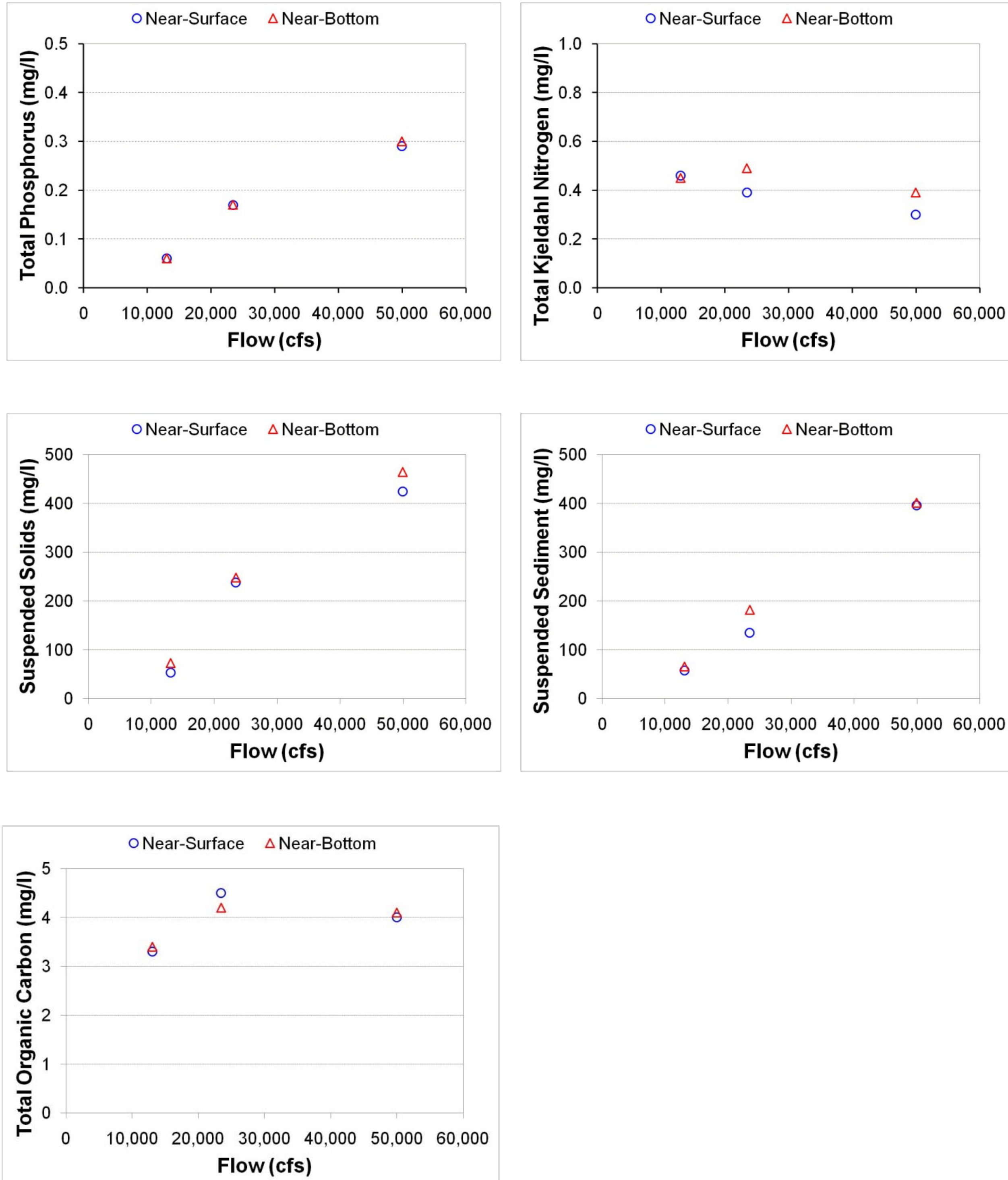

Plate 103. Comparison of flow and measured near-surface and near-bottom concentrations of total phosphorus, total Kjeldahl nitrogen, total suspended sediment, total suspended solids, and total organic carbon in the Missouri River near Williston, ND (i.e., site GARNFMORR1) during 2010.

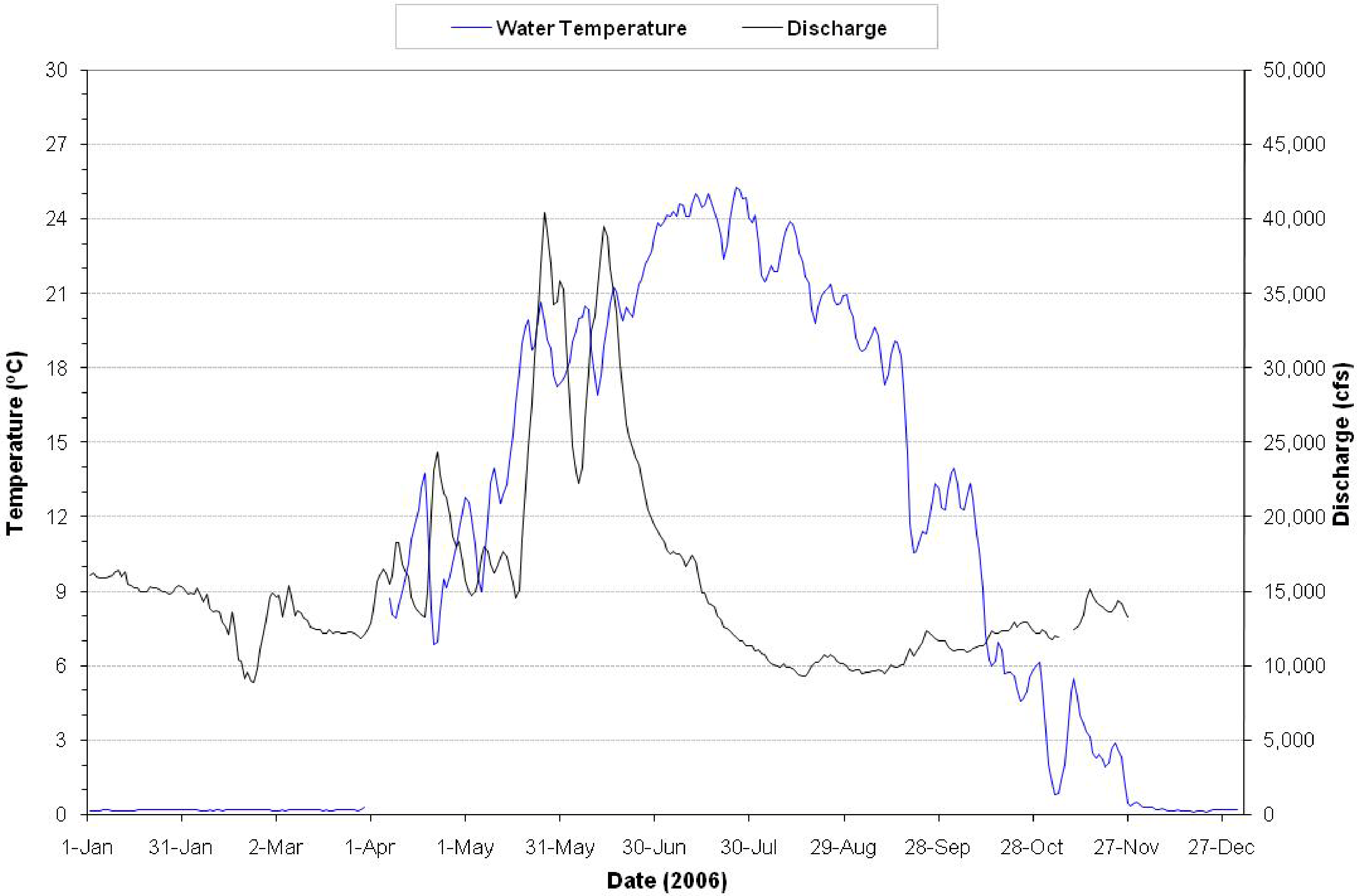

Plate 104. Mean daily water temperature and discharge of the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) for 2006. Mean temperatures based on hourly measurements recorded on the Missouri River near Williston, North Dakota (USGS gaging station 06330000). Mean daily discharge estimated by adding mean daily discharge recorded for the Missouri River near Culbertson, Montana (USGS gaging station 06185500) and the mean daily discharge recorded for the Yellowstone River near Sidney, Montana (USGS gaging station 06329500).

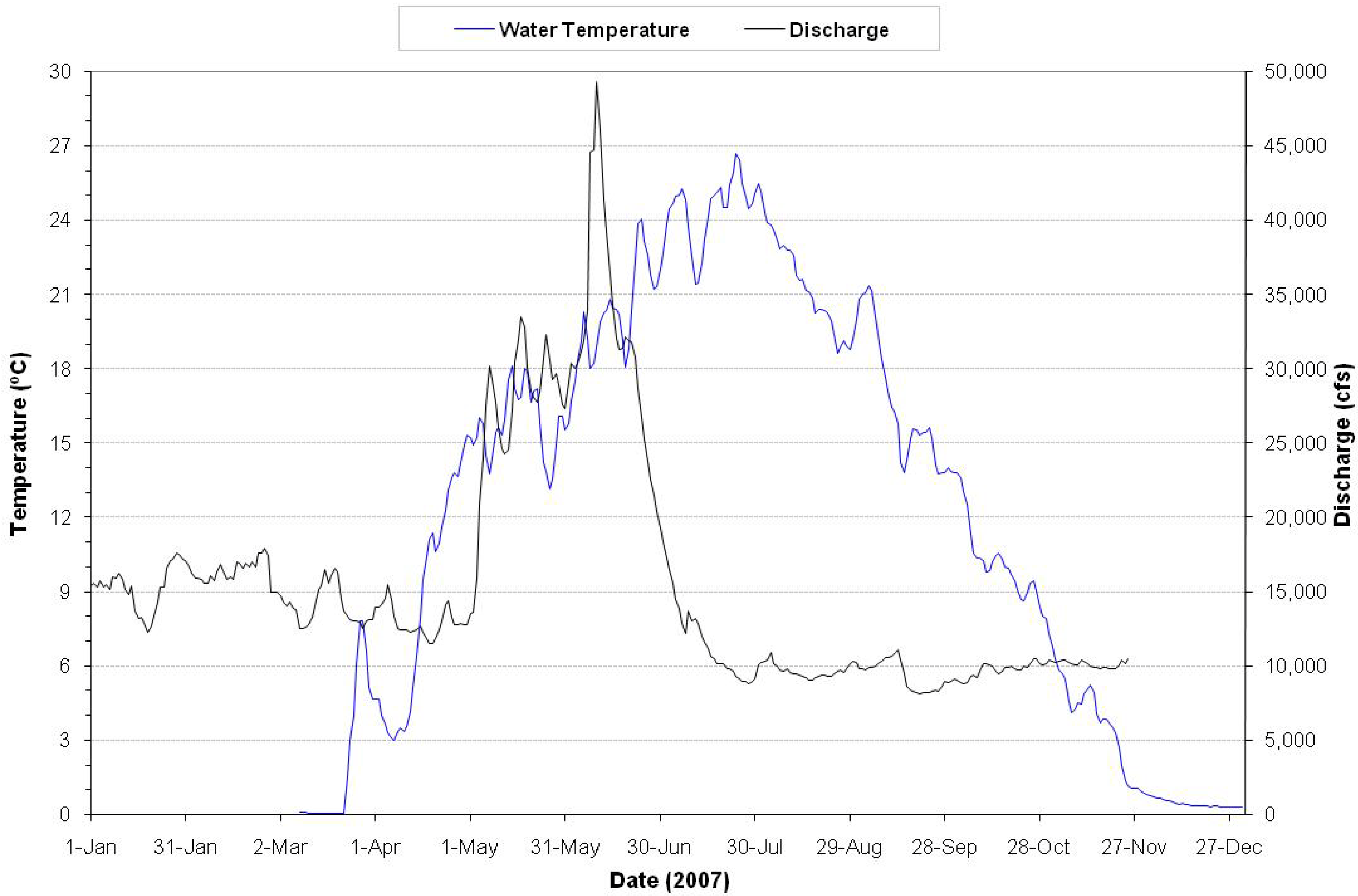

Plate 105. Mean daily water temperature and discharge of the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) for 2007. Mean temperatures based on hourly measurements recorded on the Missouri River near Williston, North Dakota (USGS gaging station 06330000). Mean daily discharge estimated by adding mean daily discharge recorded for the Missouri River near Culbertson, Montana (USGS gaging station 06185500) and the mean daily discharge recorded for the Yellowstone River near Sidney, Montana (USGS gaging station 06329500).

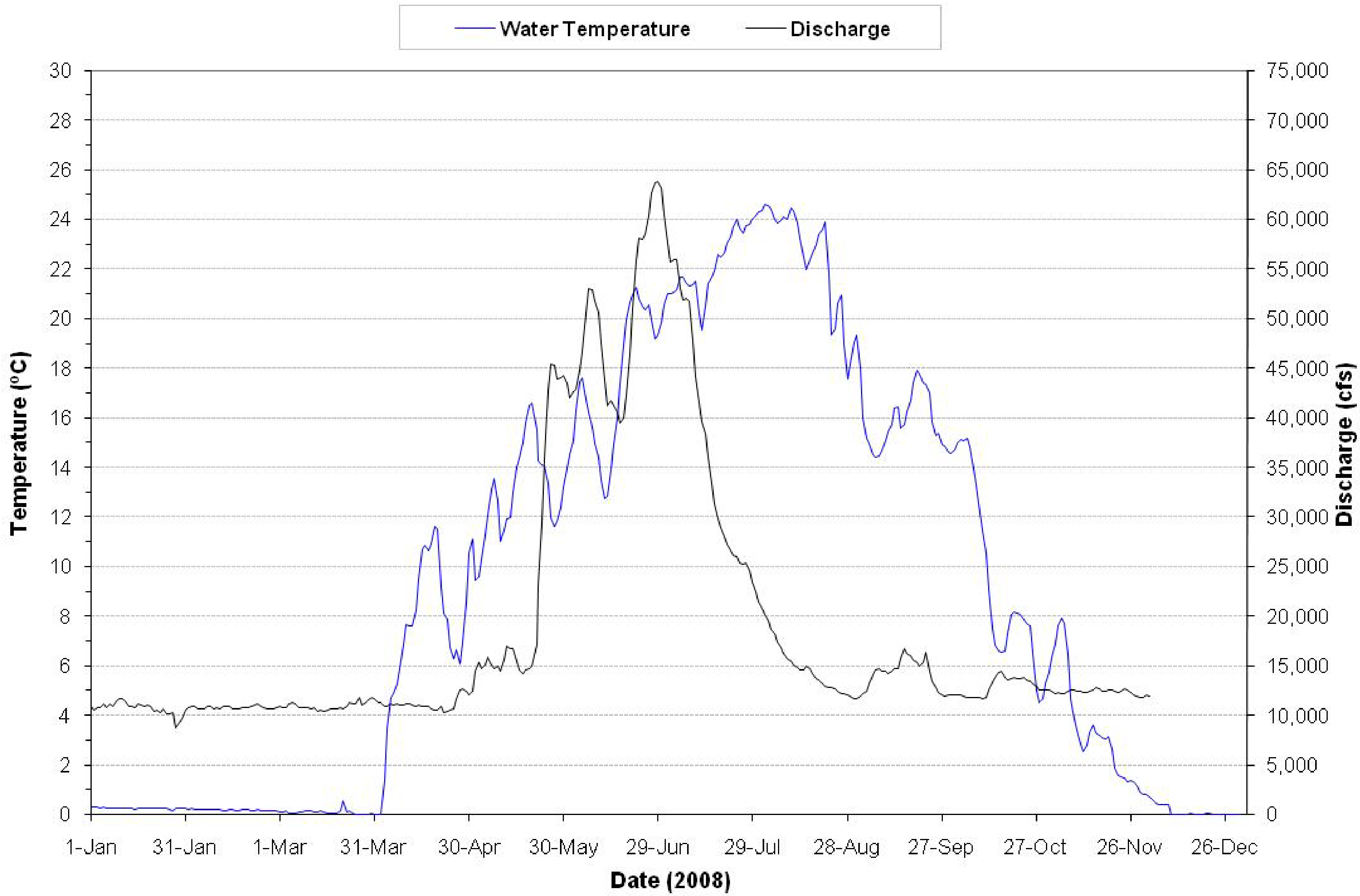

Plate 106. Mean daily water temperature and discharge of the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) for 2008. Mean temperatures based on hourly measurements recorded on the Missouri River near Williston, North Dakota (USGS gaging station 06330000). Mean daily discharge estimated by adding mean daily discharge recorded for the Missouri River near Culbertson, Montana (USGS gaging station 06185500) and the mean daily discharge recorded for the Yellowstone River near Sidney, Montana (USGS gaging station 06329500).

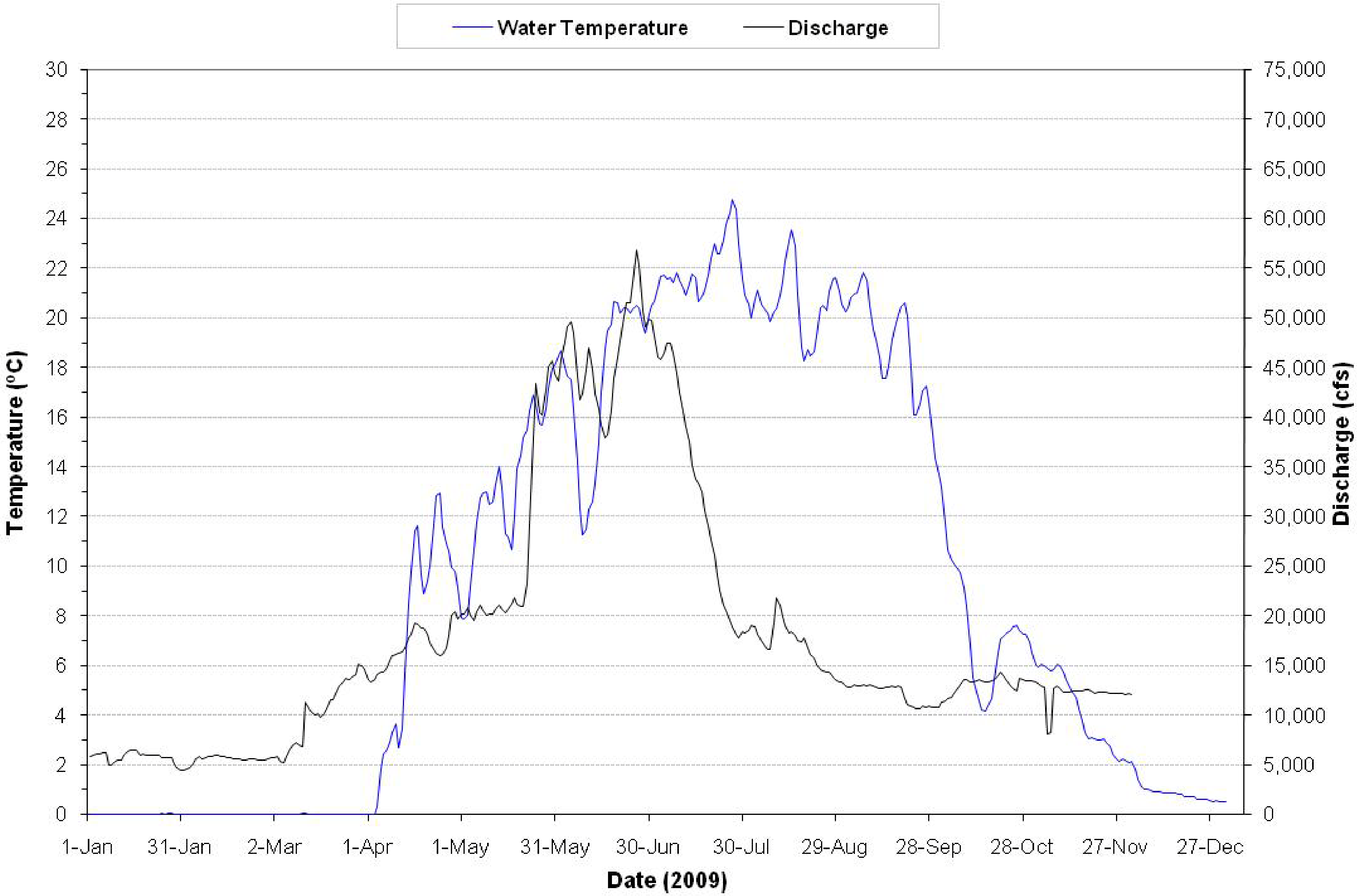

Plate 107. Mean daily water temperature and discharge of the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) for 2009. Mean temperatures based on hourly measurements recorded on the Missouri River near Williston, North Dakota (USGS gaging station 06330000). Mean daily discharge estimated by adding mean daily discharge recorded for the Missouri River near Culbertson, Montana (USGS gaging station 06185500) and the mean daily discharge recorded for the Yellowstone River near Sidney, Montana (USGS gaging station 06329500).

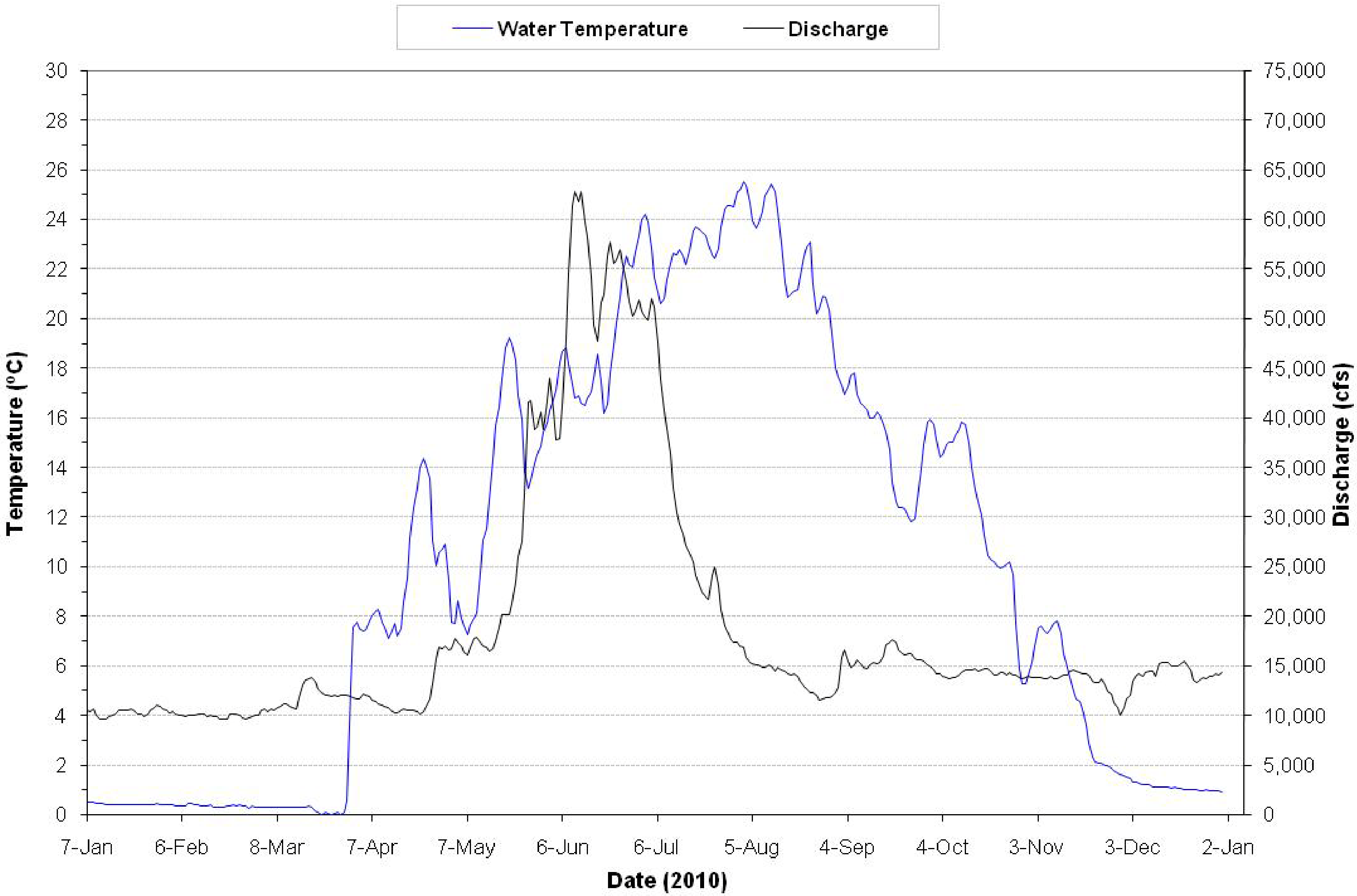

Plate 108. Mean daily water temperature and discharge of the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) for 2010. Mean temperatures based on hourly measurements recorded on the Missouri River near Williston, North Dakota (USGS gaging station 06330000). Mean daily discharge estimated by adding mean daily discharge recorded for the Missouri River near Culbertson, Montana (USGS gaging station 06185500) and the mean daily discharge recorded for the Yellowstone River near Sidney, Montana (USGS gaging station 06329500).

Plate 109. Summary of monthly water quality conditions monitored from water discharged through Garrison Dam (i.e., GARPP1) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[(A)]	No. of Obs.	Mean[(B)]	Median	Min.	Max.	State WQS Criteria[(C)]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	49	16,824	13,528	9,076	37,300	-----	-----	-----
Water Temperature (°C)	0.1	45	8.4	8.1	1.0	18.2	29.4[(1,2)]	0	0%
Dissolved Oxygen (mg/l)	0.1	44	10.3	10.5	6.6	14.2	5[(1,3)]	0	0%
Dissolved Oxygen (% Sat.)	0.1	44	90.4	93.5	67.3	105.6	-----	-----	-----
pH (S.U.)	0.1	40	8.0	8.1	6.7	8.6	7.0[(1,3)], 9.0[(1,2)]	2, 0	5%, 0%
Specific Conductance (umhos/cm)	1	44	600	598	517	815	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	39	387	373	222	548	-----	-----	-----
Turbidity (NTU)	1	39	5	2	n.d.	47	-----	-----	-----
Alkalinity, Total (mg/l)	7	49	155	154	140	186	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	48	3.3	3.1	1.3	7.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	49	7	8	n.d.	16	-----	-----	-----
Chloride, Dissolved (mg/l)	1	38	10	10	8	12	100[(1,2)]	0	0%
Color, True (APHA)	1	8	6	6	4	8	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	49	411	406	300	636	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	49	-----	n.d.	n.d.	0.23	6.9 [(1,2,4)], 2.0 [(1,4,5)]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	49	-----	0.03	n.d.	2.4	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	49	-----	0.07	n.d.	0.20	1.0[(1,2)]	0	0%
Nitrogen, Total (mg/l)	0.1	49	0.5	0.4	n.d.	2.4	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	47	-----	n.d.	n.d.	0.05	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	49	-----	0.02	n.d.	0.11	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	49	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	49	155	151	135	190	250[(1,2)]	0	0%
Suspended Solids, Total (mg/l)	4	49	-----	N.d.	n.d.	15	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for Class 1 streams.
(2) Daily maximum criterion (monitoring results directly comparable to criterion).
(3) Daily minimum criterion (monitoring results directly comparable to criterion).
(4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(5) 30-day average criterion (monitoring results not directly comparable to criterion).

Plate 110. Summary of monthly water quality conditions monitored from water discharged through Garrison Dam (i.e., GARPP1) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Aluminum, Total (ug/l)	25	4	140	102	60	297	750(6)	0	0%
Antimony, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	0.5	-----	-----	-----
Antimony, Total (ug/l)	0.5	4	-----	n.d.	n.d.	0.6	5.6(8)	0	0%
Arsenic, Dissolved (ug/l)	1	4	-----	1	n.d.	2	-----	-----	-----
Arsenic, Total (ug/l)	1	4	2	2	1	2	340(1), 150(2), 10(3)	0	0%
Barium, Dissolved (ug/l)	5	4	51	50	47	58	-----	-----	-----
Barium, Total (ug/l)	5	4	54	53	50	60	1,000(8)	0	0%
Beryllium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Beryllium, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	4(8)	0	0%
Cadmium, Dissolved (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Cadmium, Total (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	4.0(6), 0.43(7), 5(8)	0	0%
Calcium, Dissolved (mg/l)	0.4	6	48	48	42	54	-----	-----	-----
Chromium, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Chromium, Total (ug/l)	10	4	-----	n.d.	n.d.	n.d.	2,997(6), 143(7), 100(8)	0	0%
Copper, Dissolved (ug/l)	2	6	-----	n.d.	n.d.	10	-----	-----	-----
Copper, Total (ug/l)	2	4	-----	n.d.	n.d.	31	25(6), 16(7), 1,000(8)	1, 1, 0	25%. 25%, 0%
Hardness, Total (mg/l)	0.4	5	196	186	169	223	-----	-----	-----
Iron, Dissolved (ug/l)	40	8	-----	n.d.	n.d.	10	-----	-----	-----
Iron, Total (ug/l)	40	14	193	95	20	1,401	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Lead, Total (ug/l)	0.5	4	-----	n.d.	n.d.	3.4	180(6), 7.0(7), 15(8)	0	0%
Magnesium, Dissolved (mg/l)	0.4	6	19	19	17	21	-----	-----	-----
Manganese, Dissolved (ug/l)	2	16	-----	n.d.	n.d.	12	-----	-----	-----
Manganese, Total (ug/l)	2	16	-----	4	n.d.	25	-----	-----	-----
Mercury, Dissolved (ug/l)	0.02	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Mercury, Total (ug/l)	0.02	6	-----	n.d.	n.d.	n.d.	1.7(6), 0.012(7), 0.05(8)	0, b.d., 0	0%
Nickel, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Nickel, Total (ug/l)	10	4	-----	n.d.	n.d.	n.d.	793(6), 88(7), 100(8)	0	0%
Selenium, Total (ug/l)	1	4	-----	n.d.	n.d.	2	20(6), 5(7), 50(8)	0	0%
Silver, Dissolved (ug/l)	1	6	-----	n.d.	n.d.	n.d.	-----	-----	-----
Silver, Total (ug/l)	1	4	-----	n.d.	n.d.	n.d.	14(6)	0	0%
Sodium, Dissolved (mg/l)	0.4	1	58	58	58	58	-----	-----	-----
Thallium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Total (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	0.24(7)	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	28	-----	-----	-----
Zinc, Total (ug/l)	10	4	-----	n.d.	n.d.	82	213(6,7), 7,400(8)	0	0%
Pesticide Scan (ug/l)(D)	0.05(E)	5	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

(A) Results for iron (dissolved and total) and manganese (dissolved and total) include some monthly samples.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for Class 1 streams.

(2) Daily maximum criterion (monitoring results directly comparable to criterion).

(3) Daily minimum criterion (monitoring results directly comparable to criterion).

(4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(5) 30-day average criterion (monitoring results not directly comparable to criterion).

(6) Acute criterion for aquatic life.

(7) Chronic criterion for aquatic life.

(8) Human health criterion for surface waters.

Note: Some of North Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

(E) Detection limits vary by pesticide – 0.05 ug/l is a median detection limit for the pesticides in the pesticide scan.

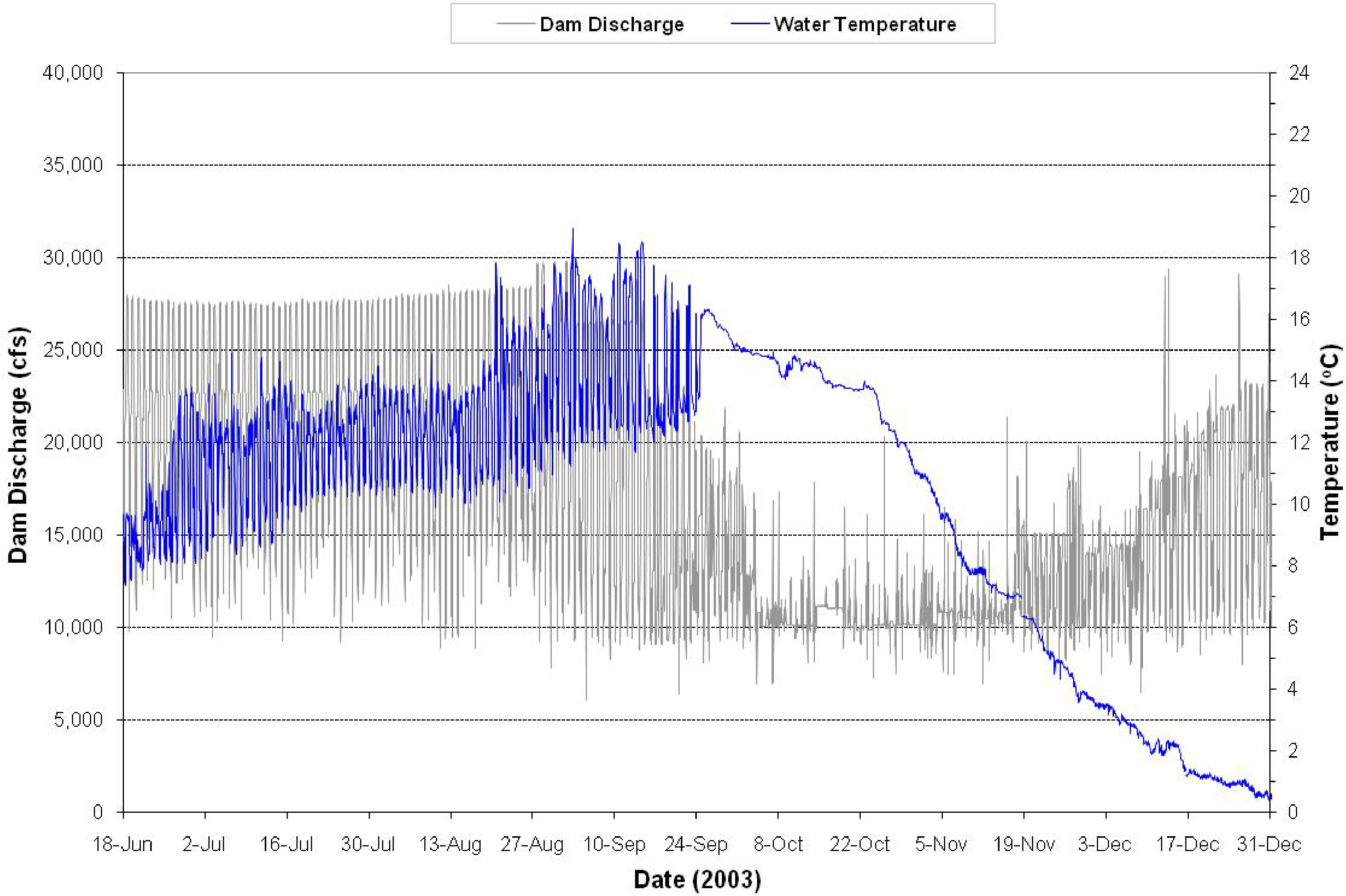

Plate 111. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period June through December 2003.

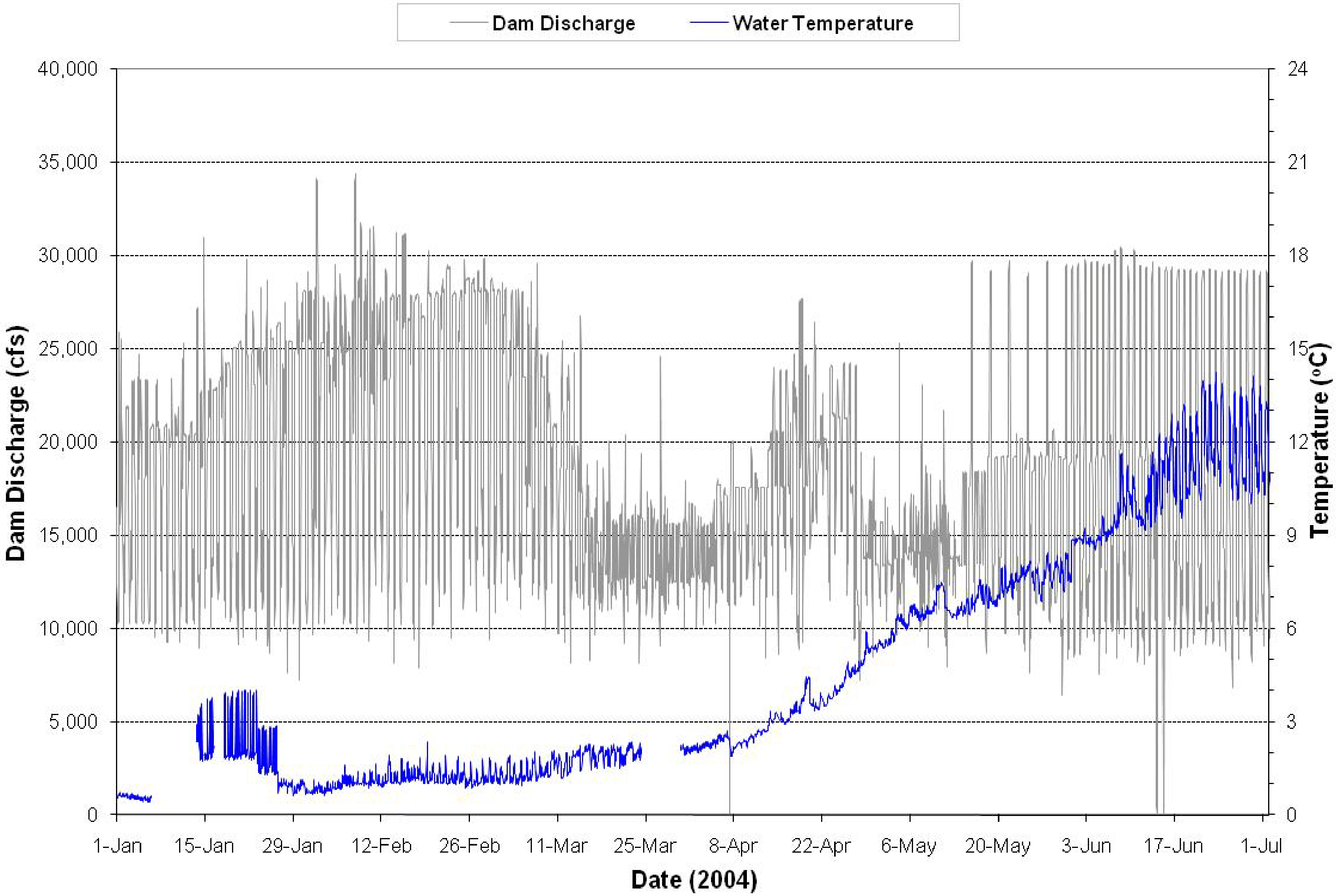

Plate 112. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2004.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

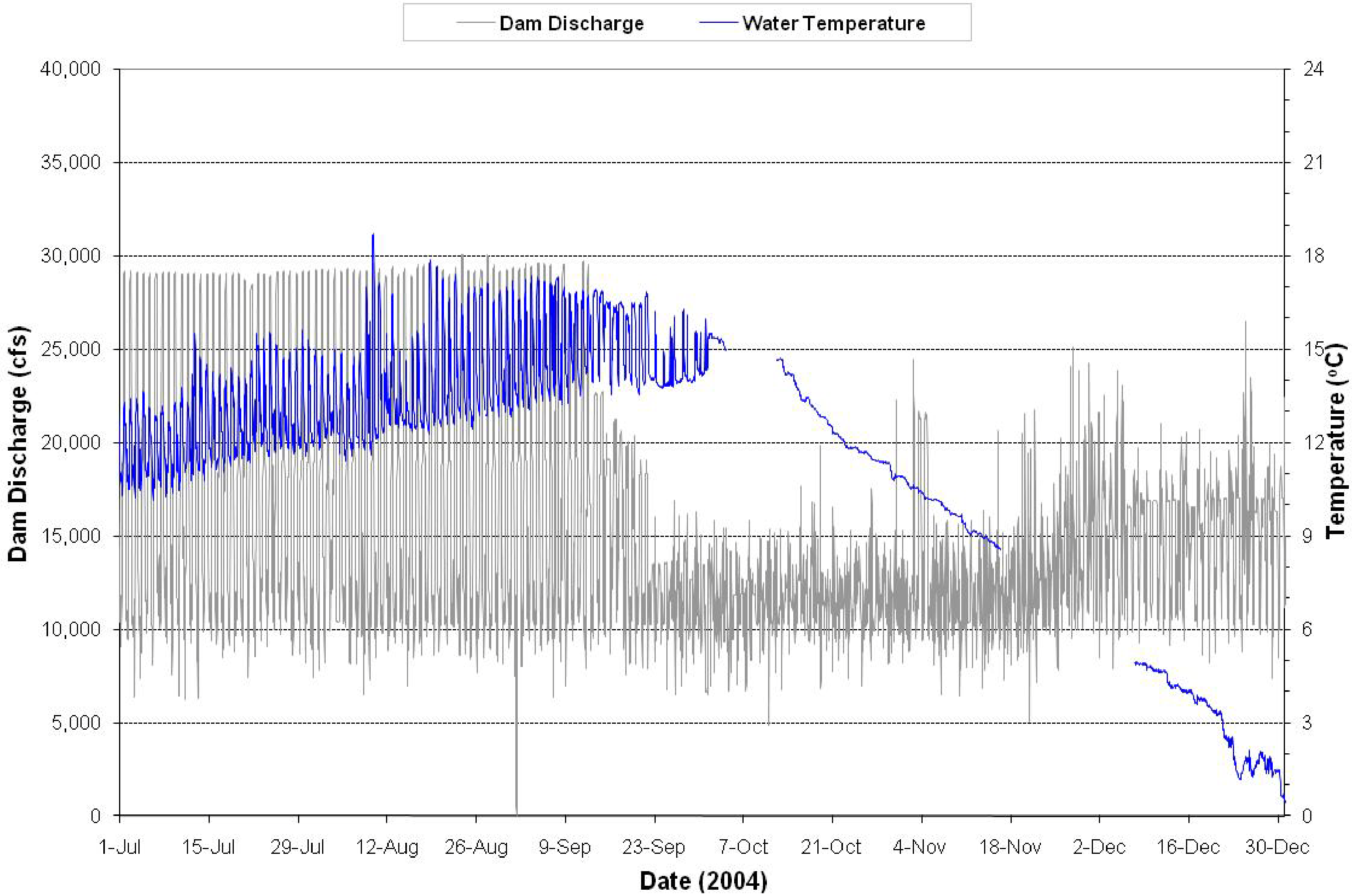

Plate 113. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2004.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

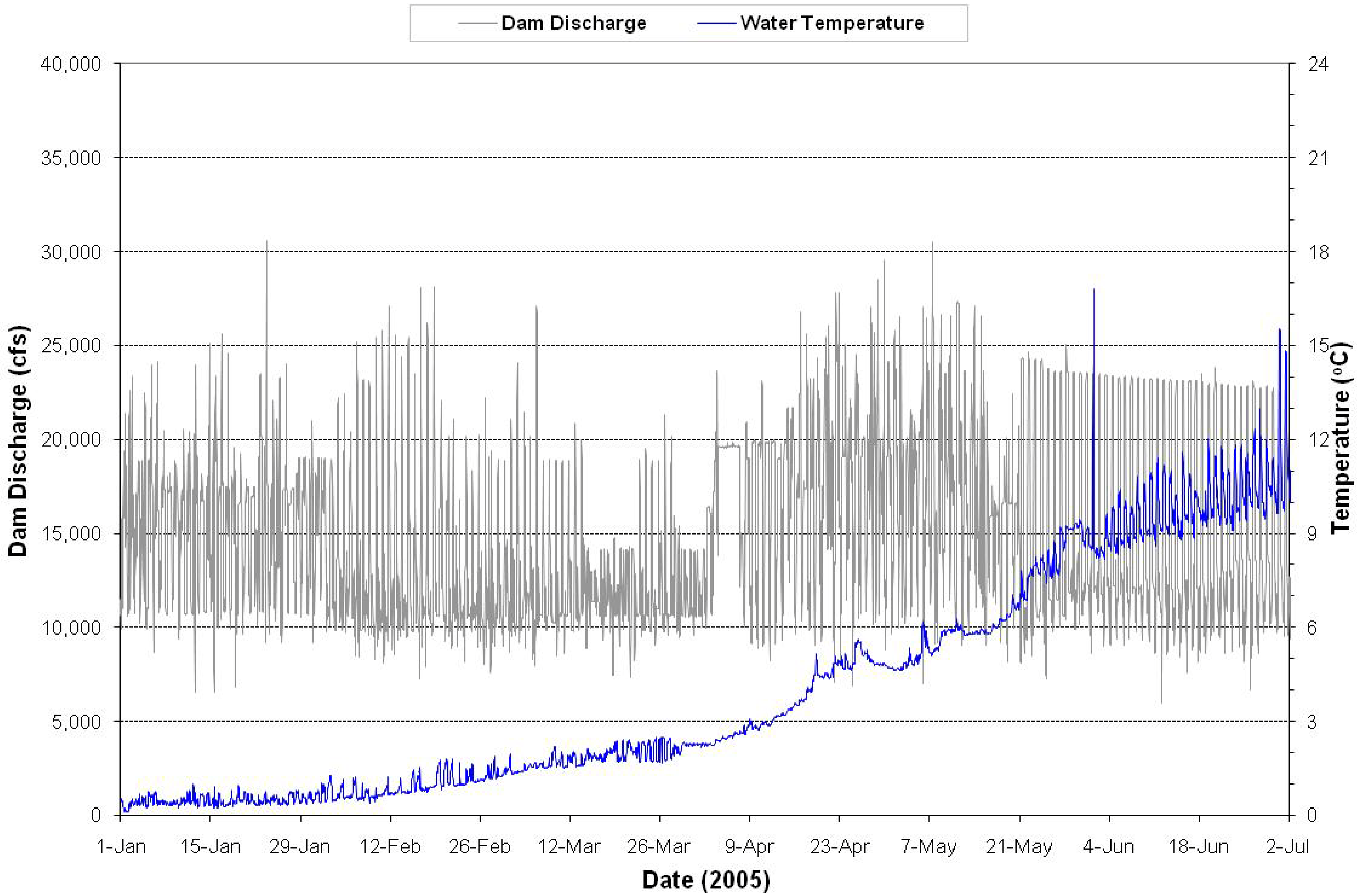

Plate 114. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2005.

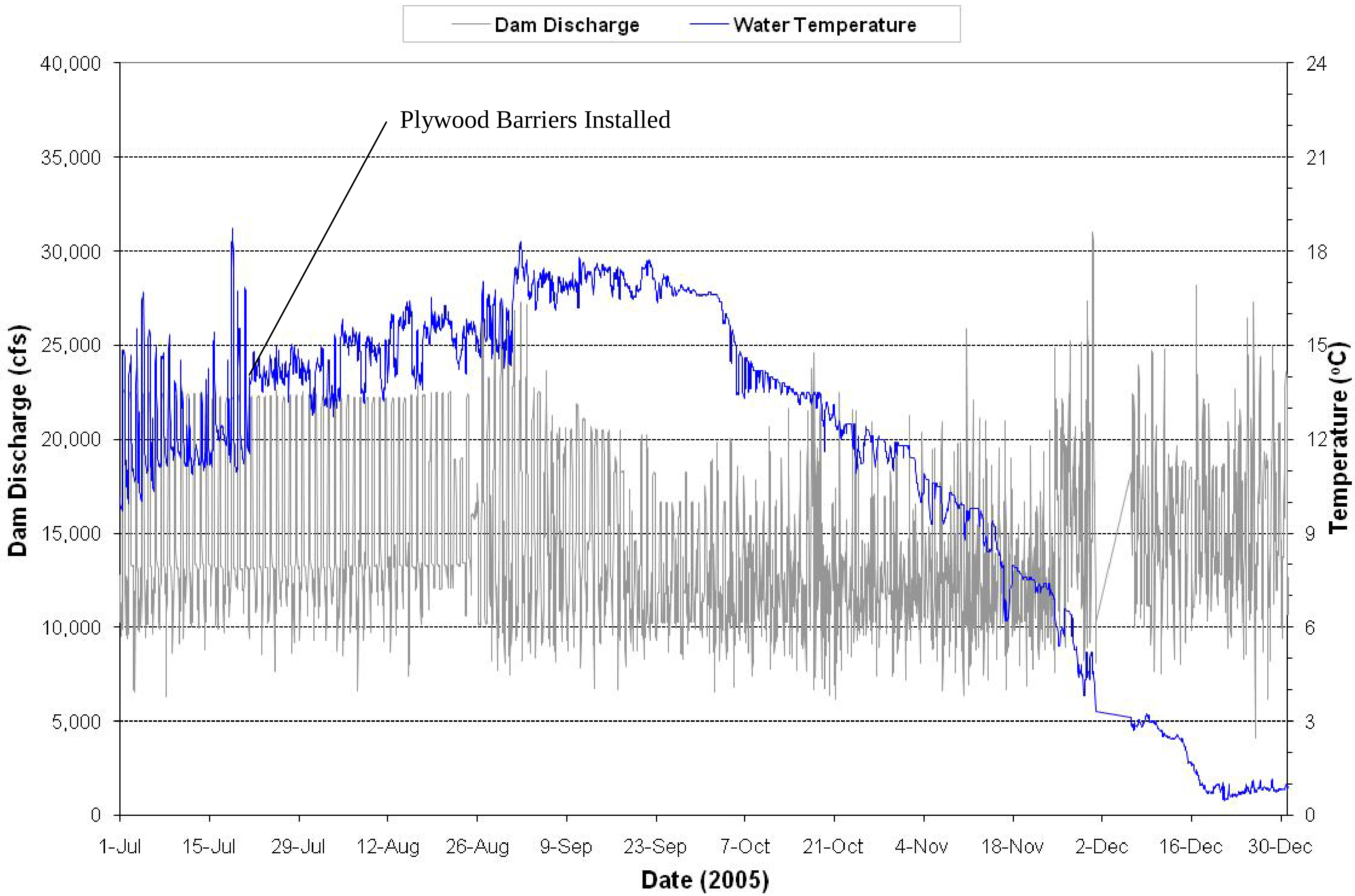

Plate 115. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2005.

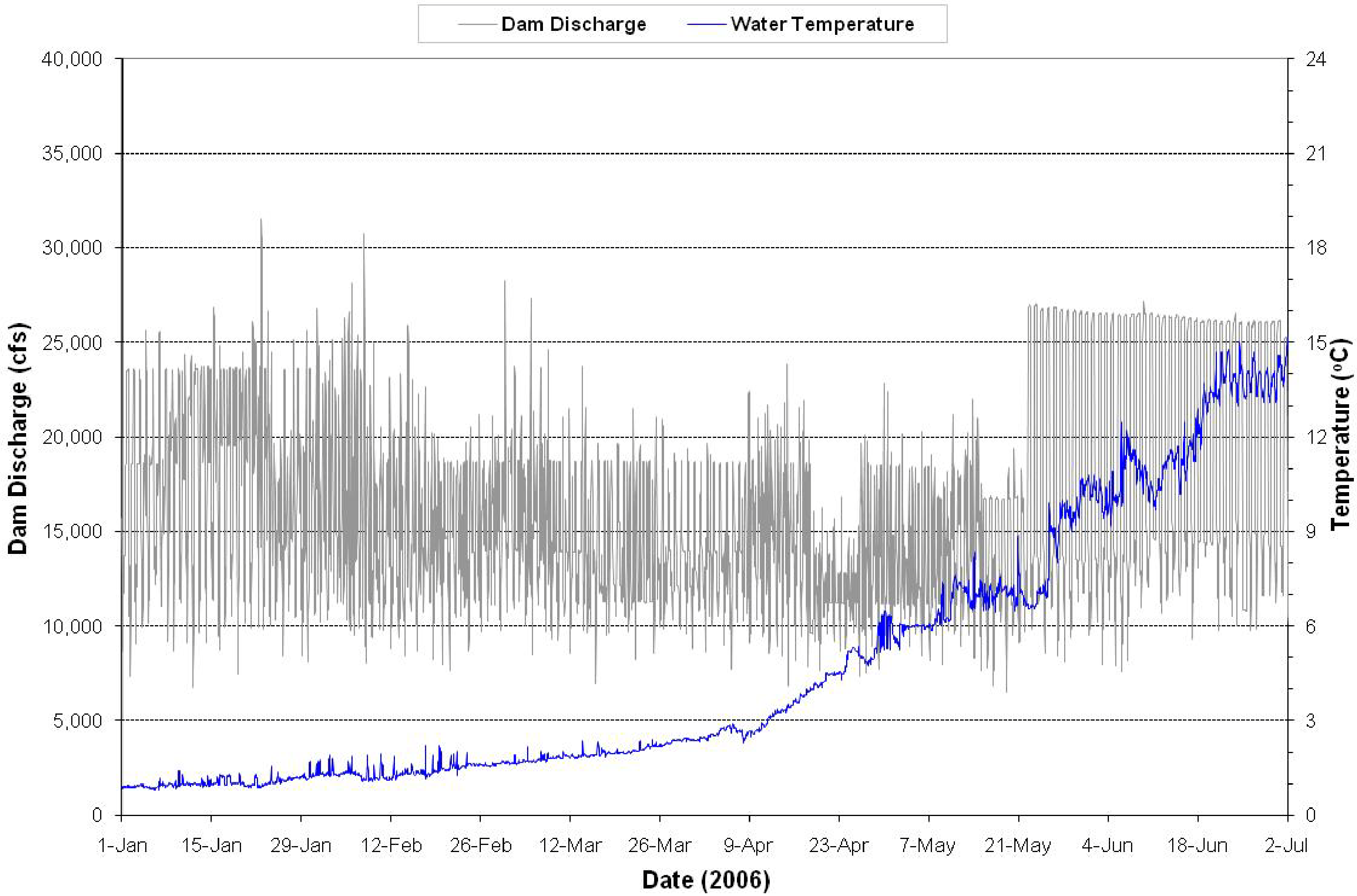

Plate 116. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2006.

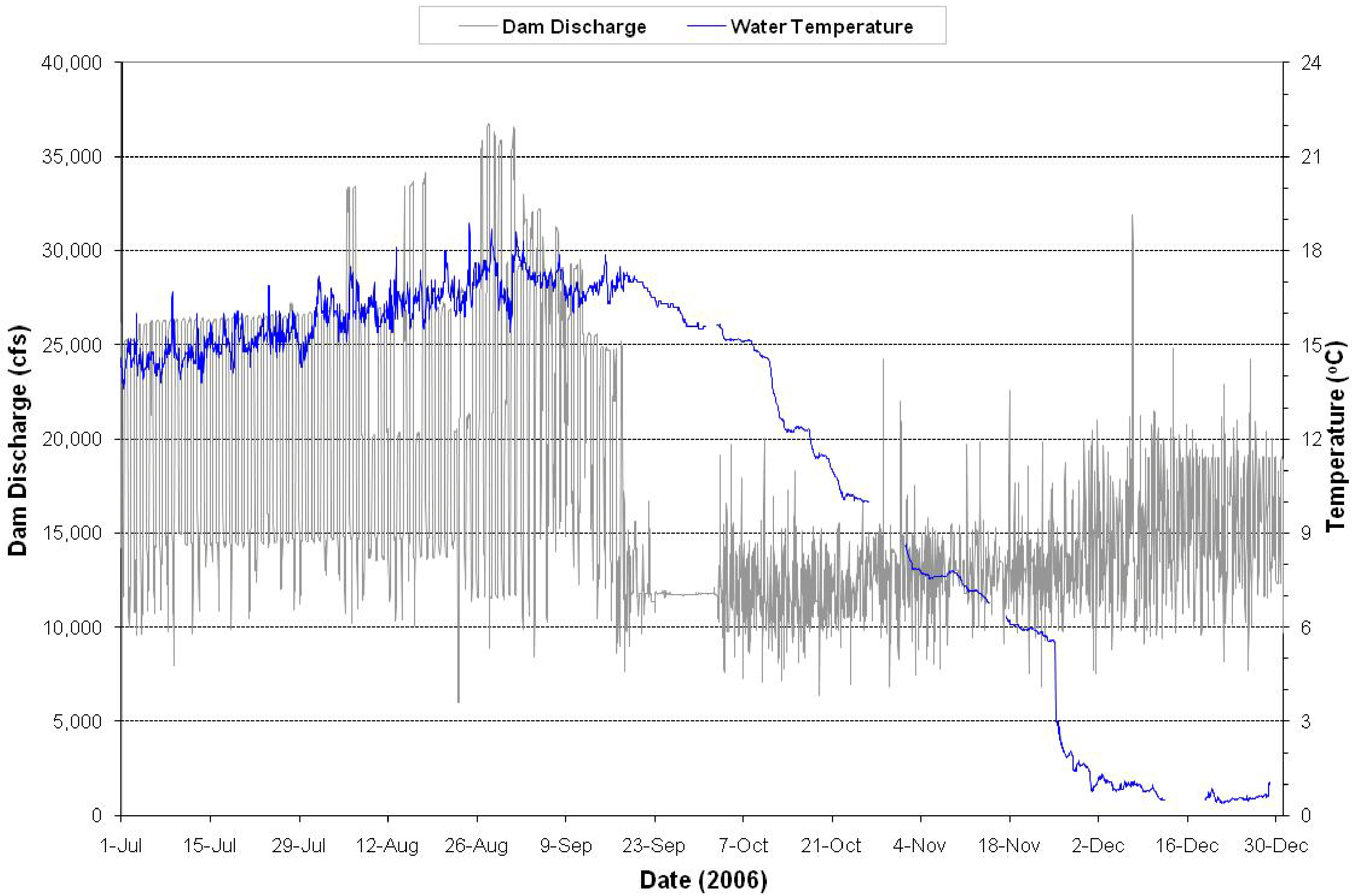

Plate 117. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2006.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

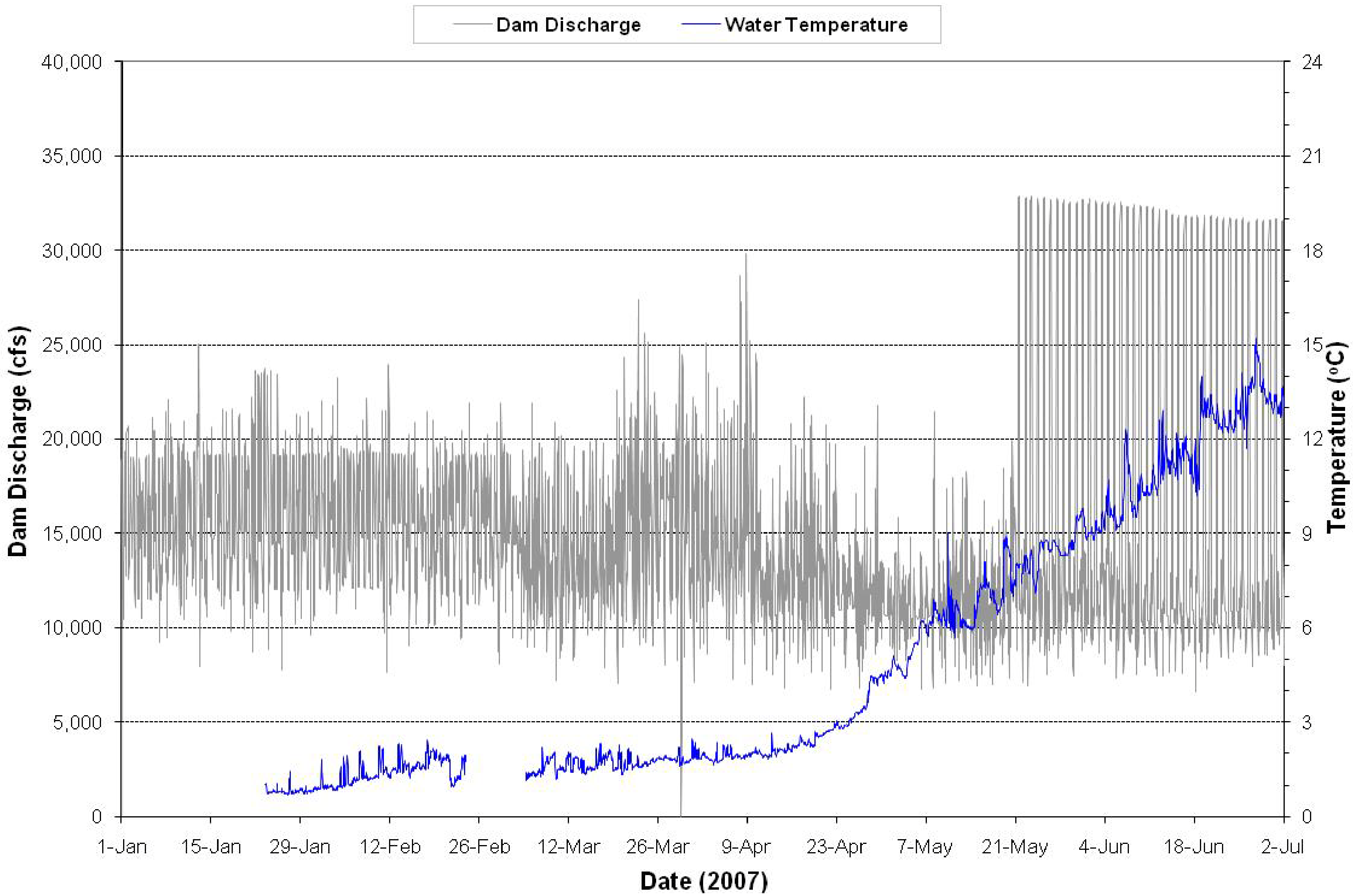

Plate 118. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2007.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

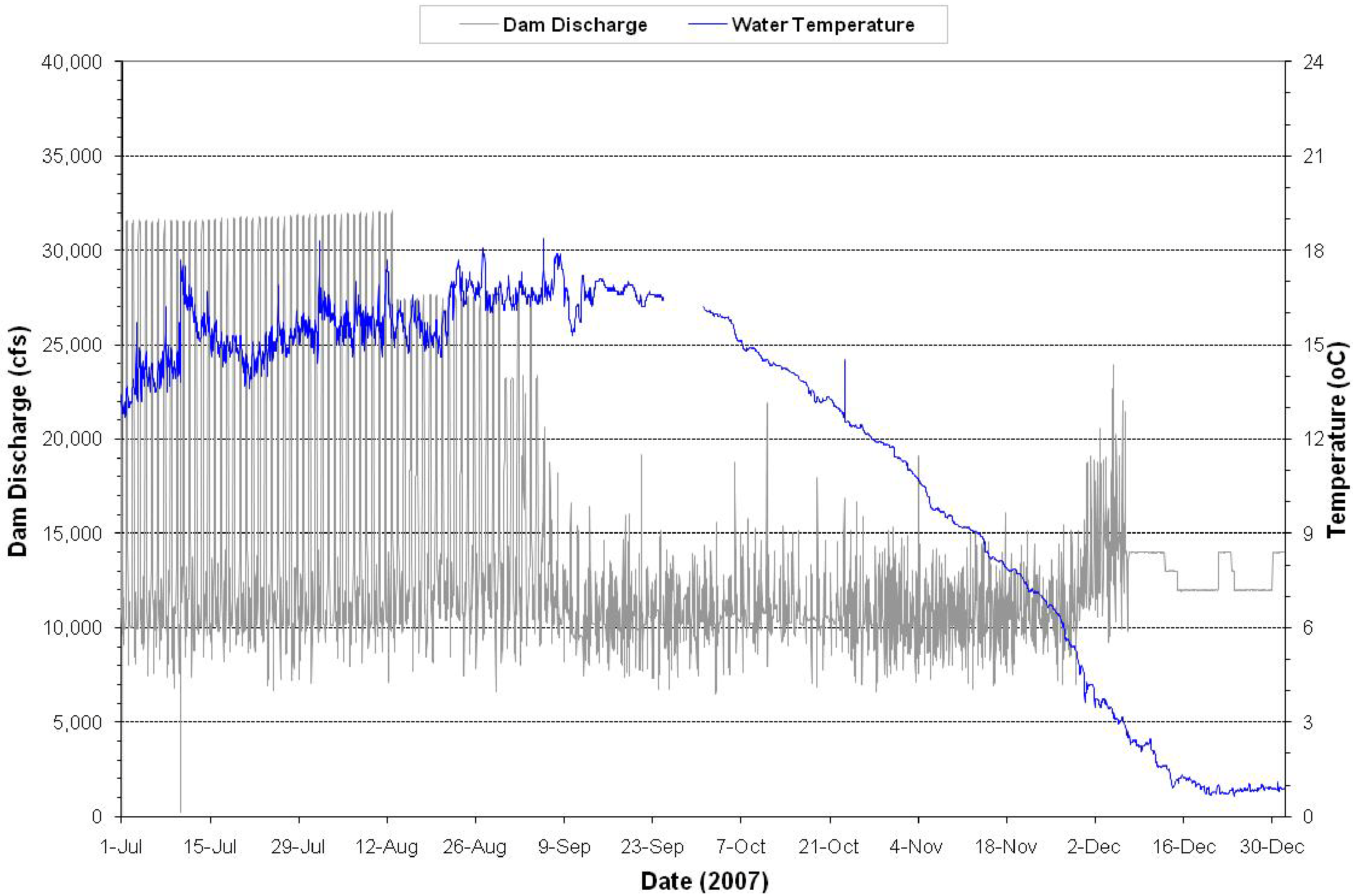

Plate 119. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

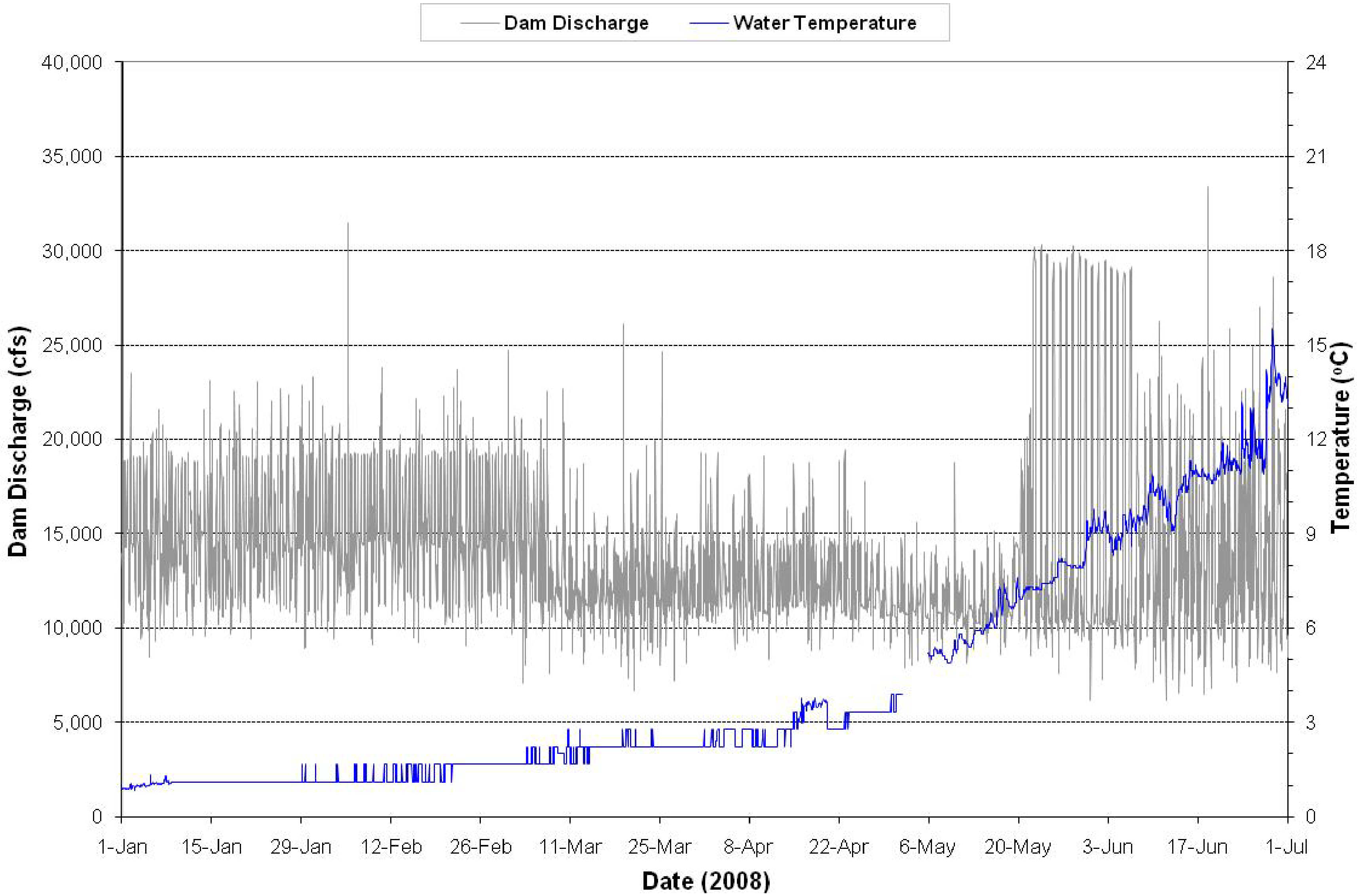

Plate 120. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2008.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

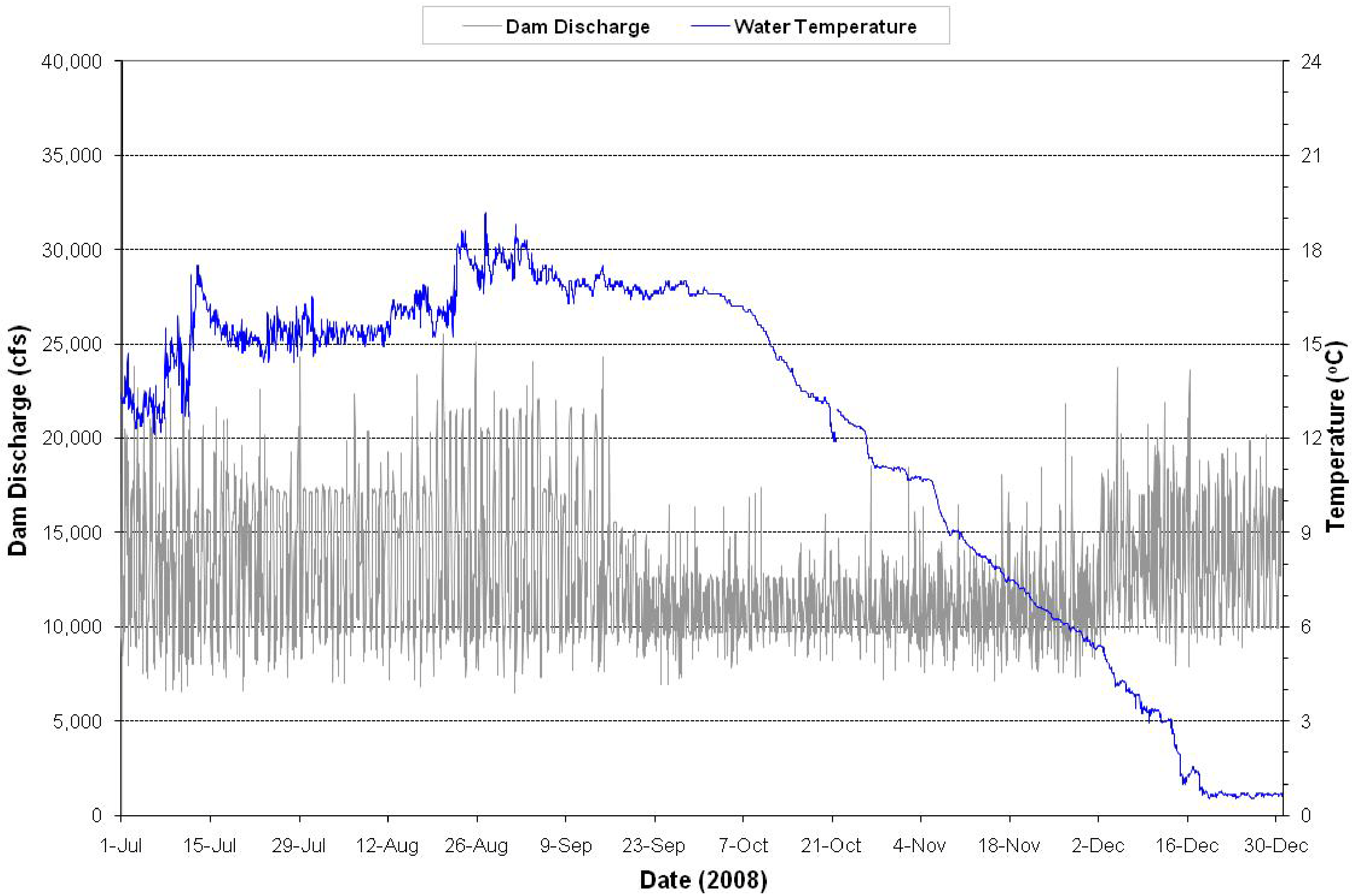

Plate 121. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2008.

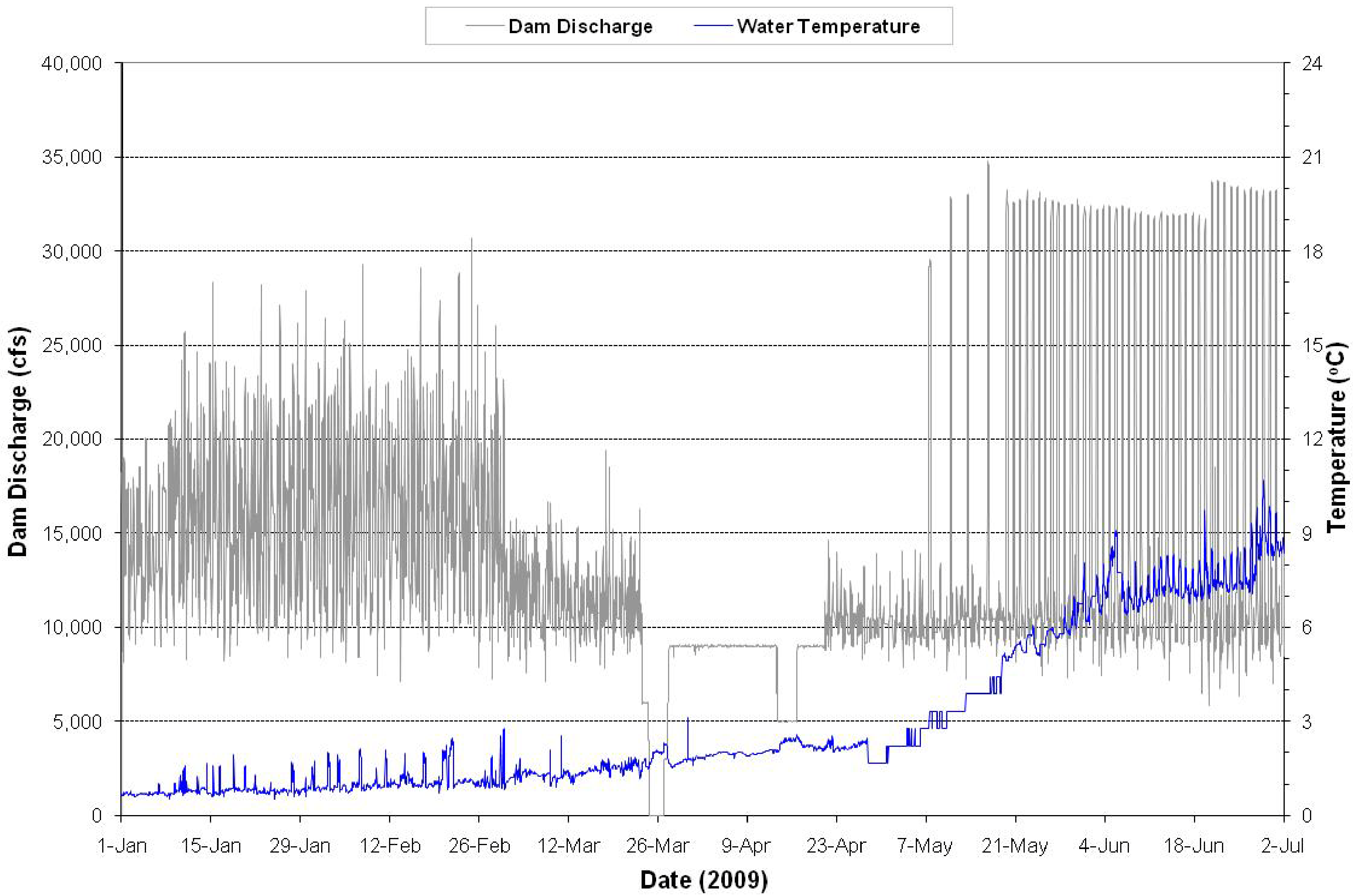

Plate 122. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2009.

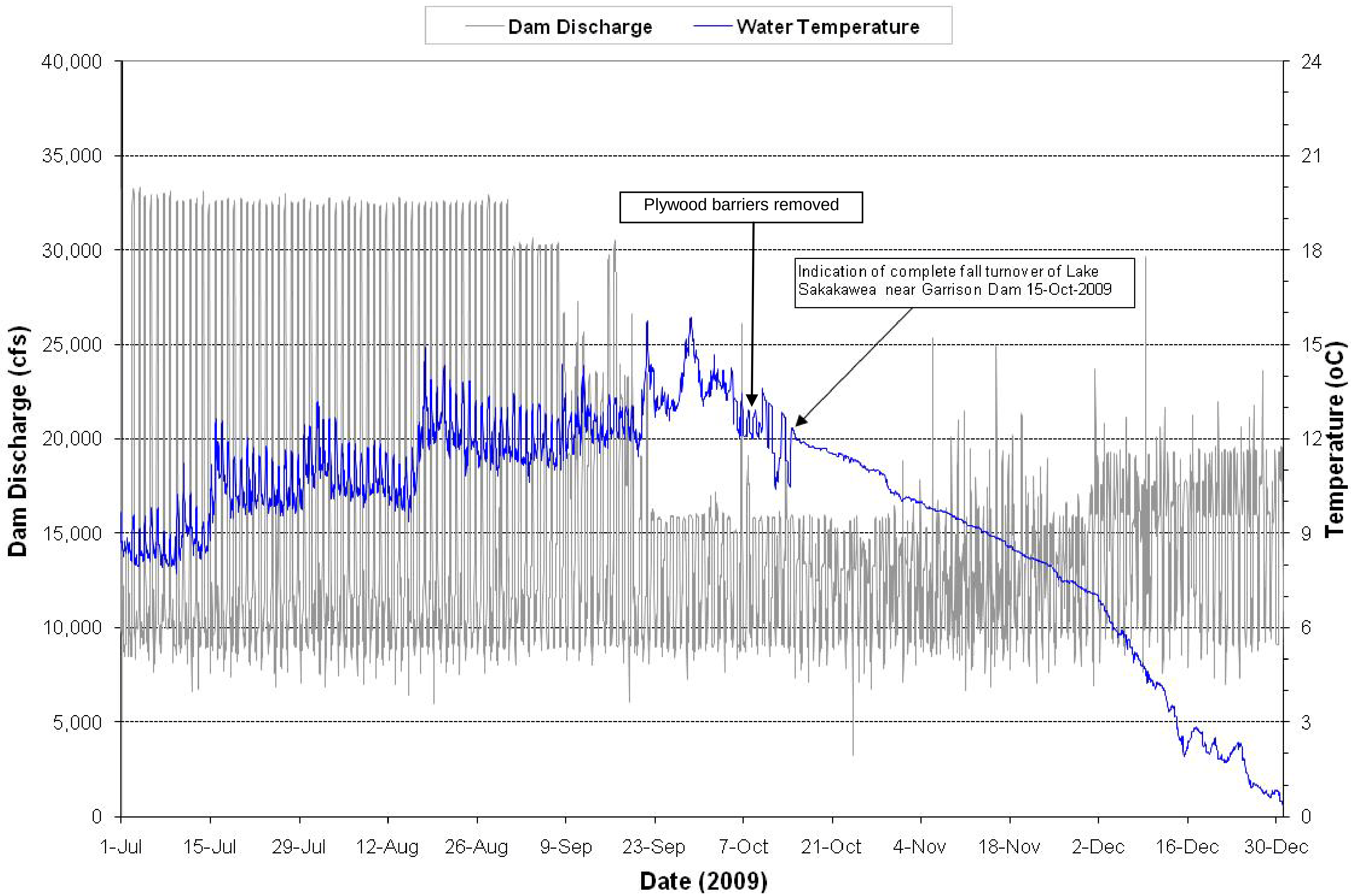

Plate 123. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2009.

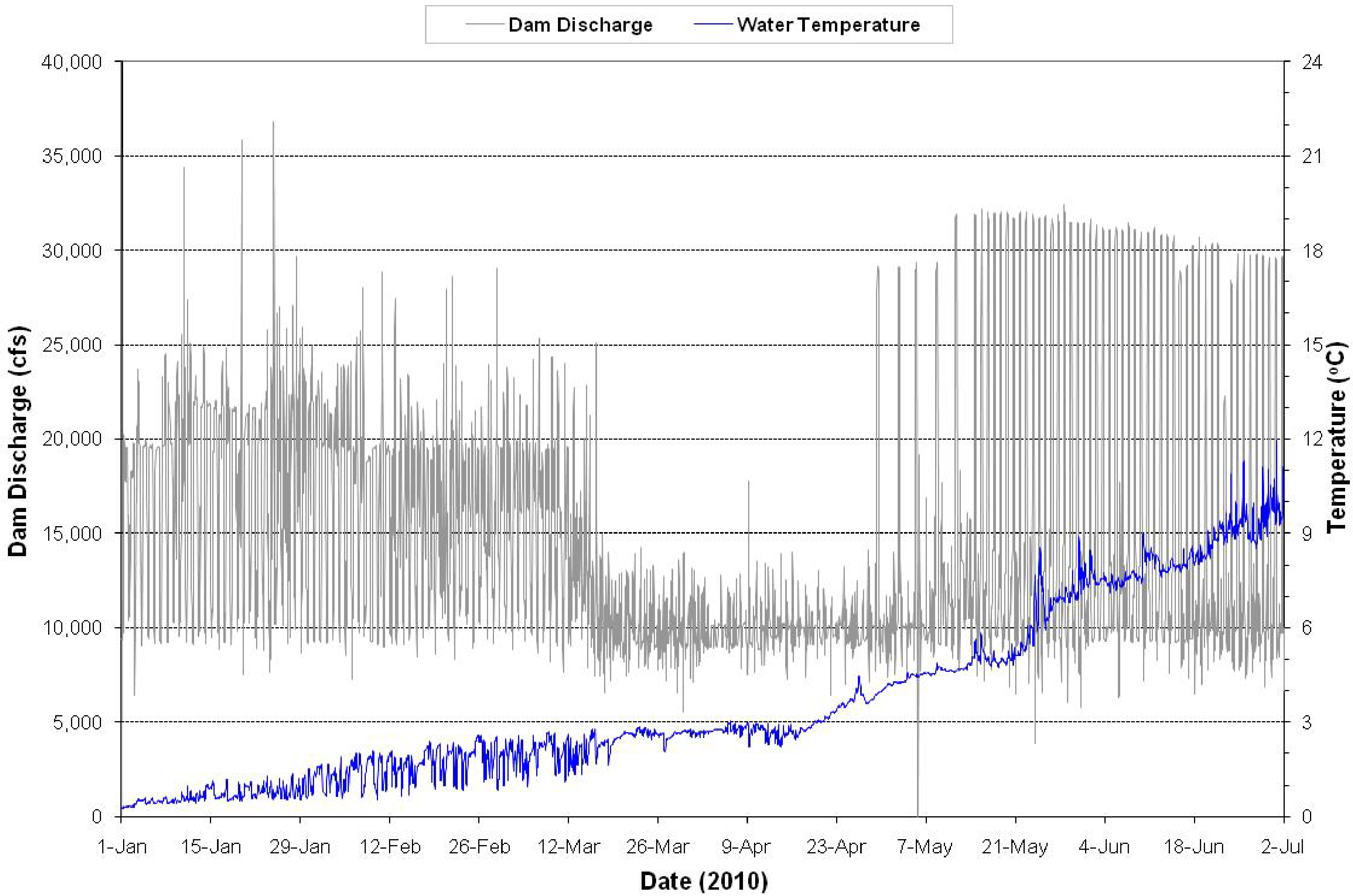

Plate 124. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2010.

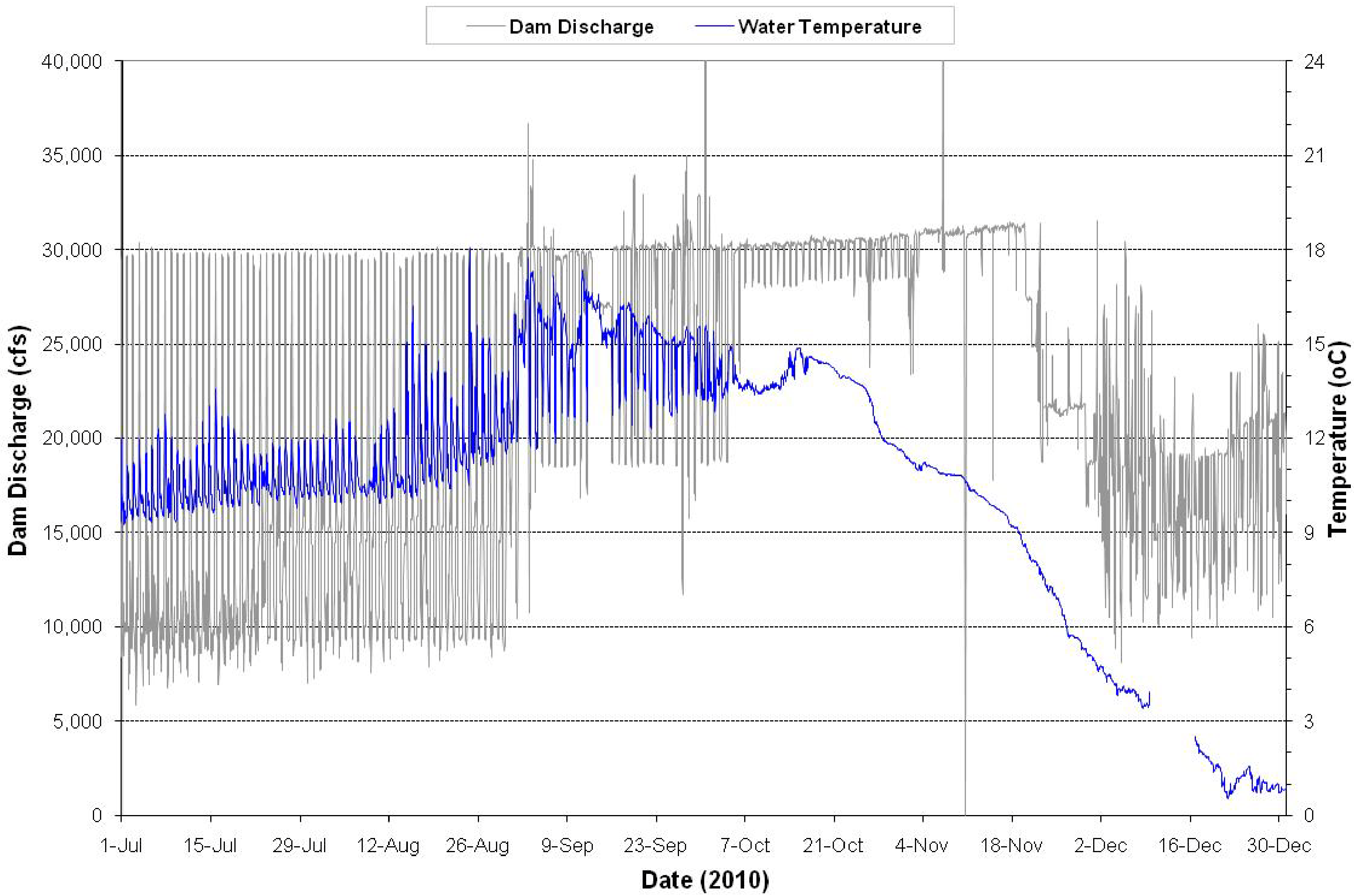

Plate 125. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2010.

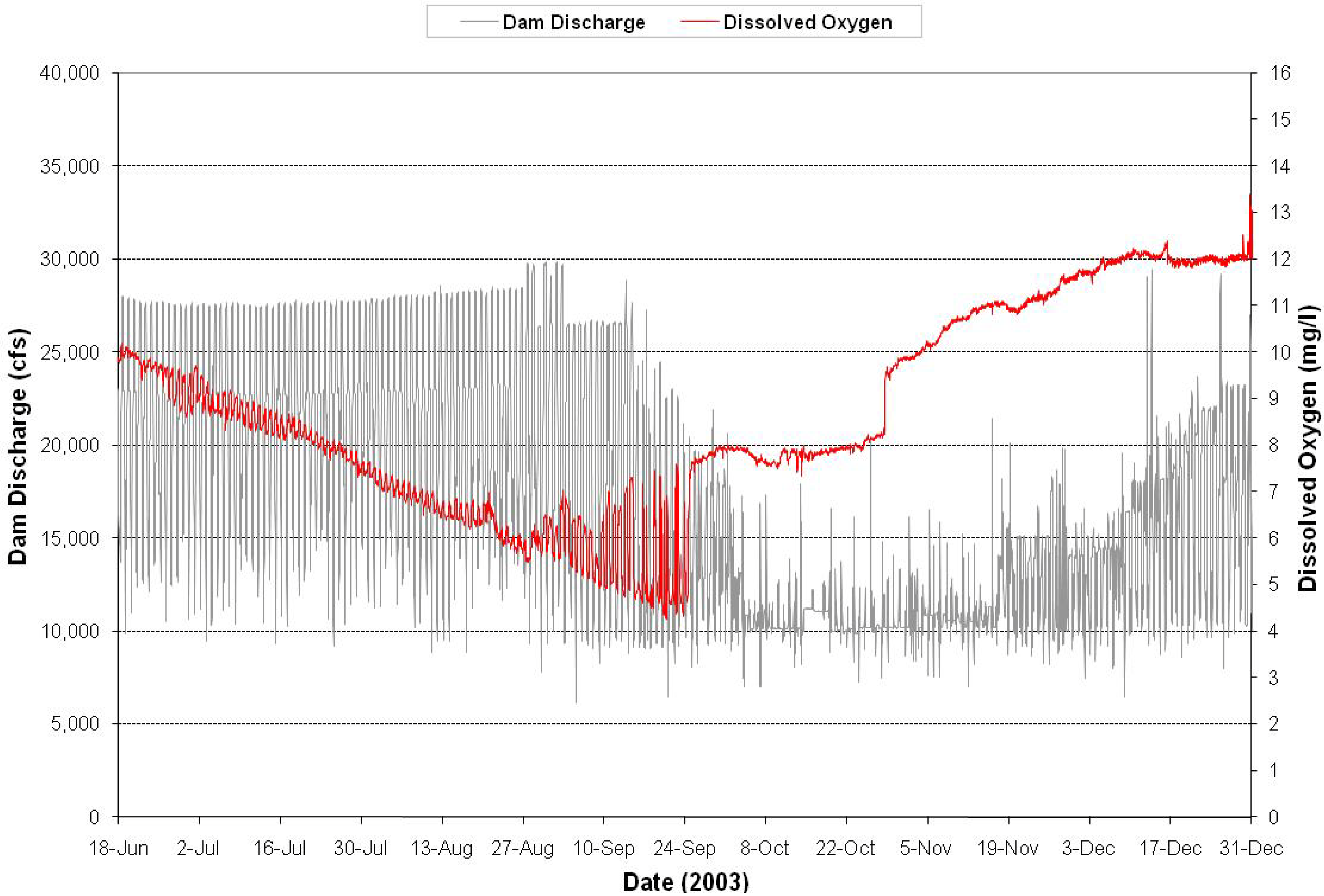

Plate 126. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period June through December 2003.

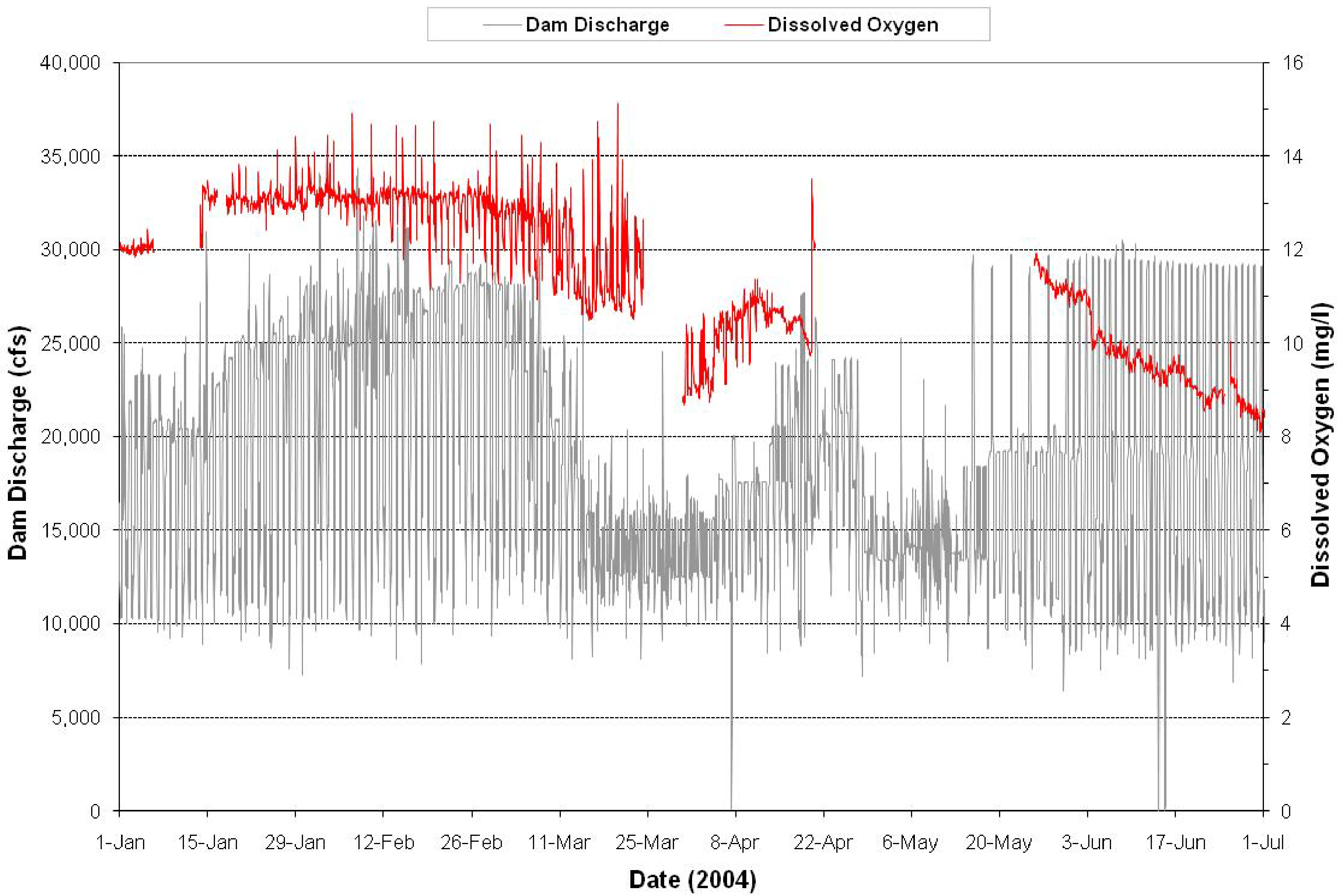

Plate 127. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2004.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

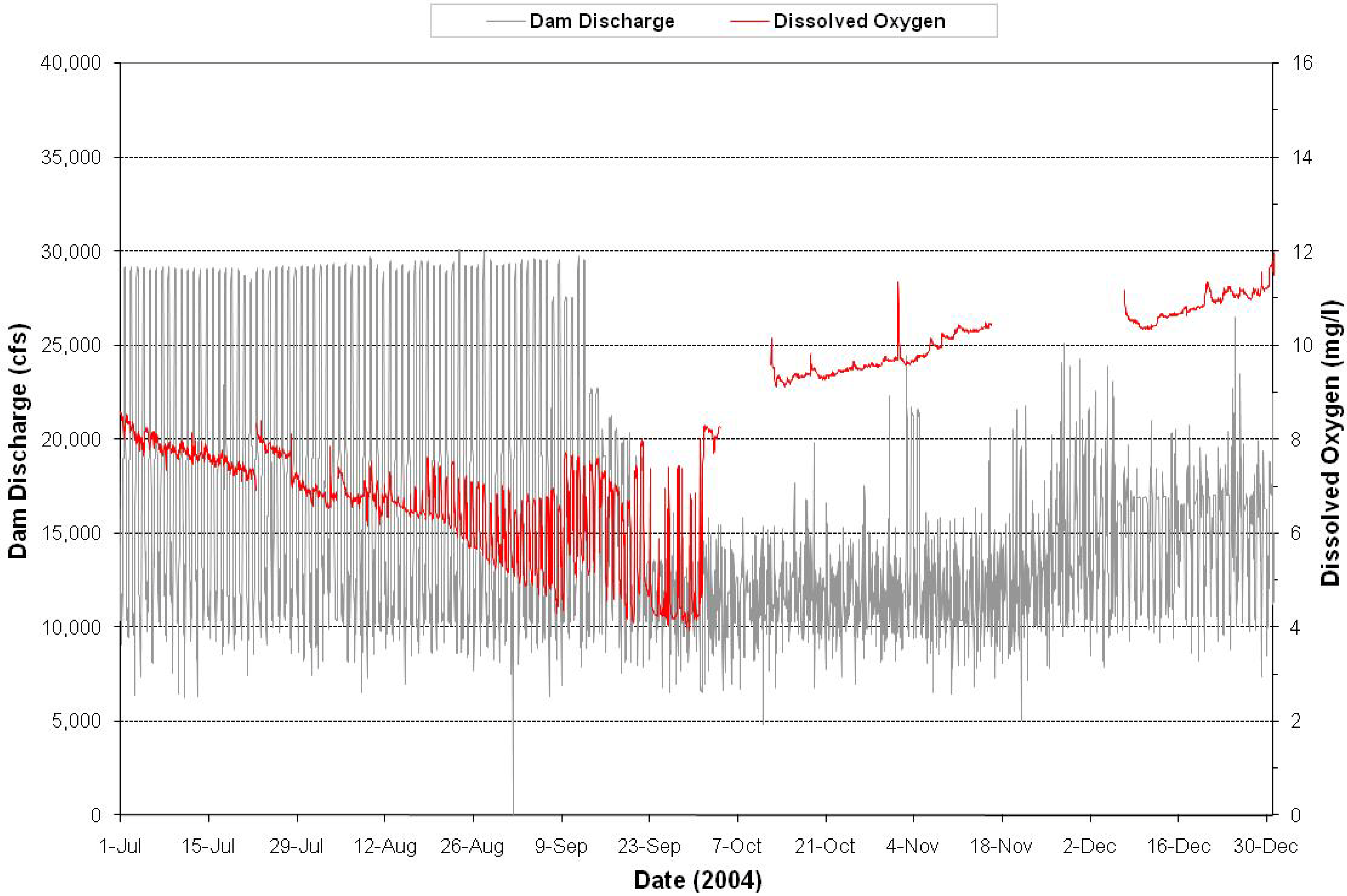

Plate 128. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2004.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

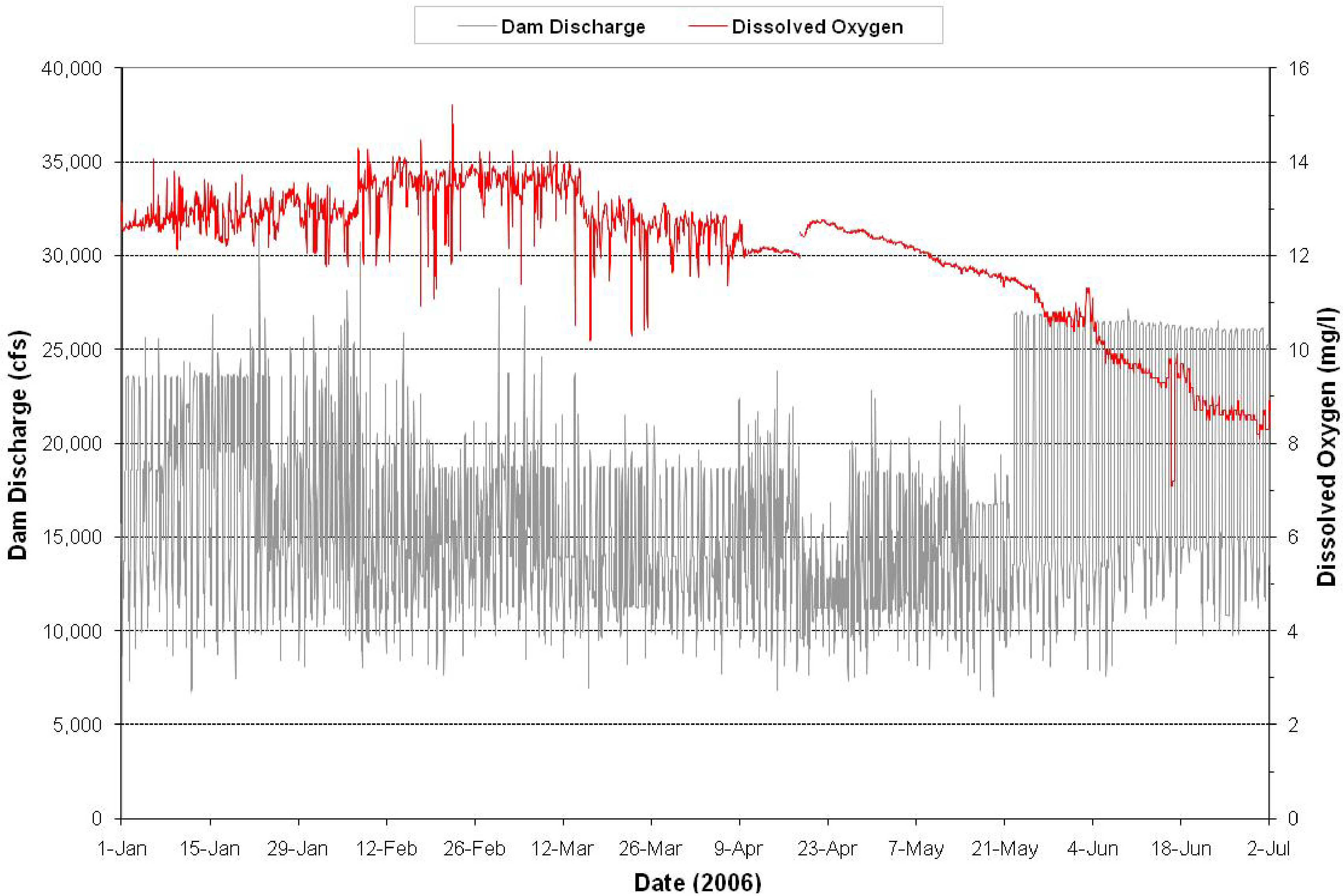

Plate 129. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2005.

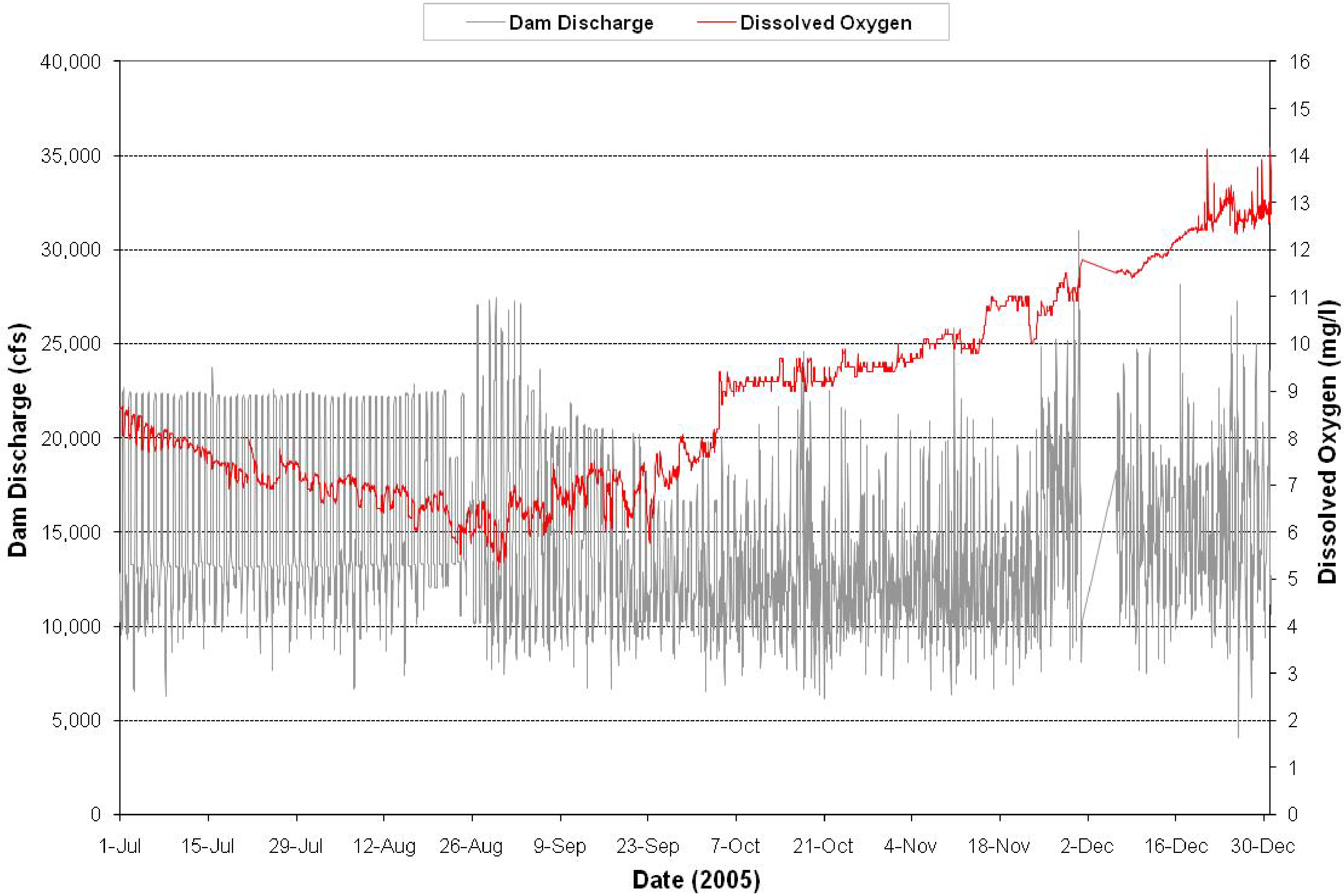

Plate 130. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2005.

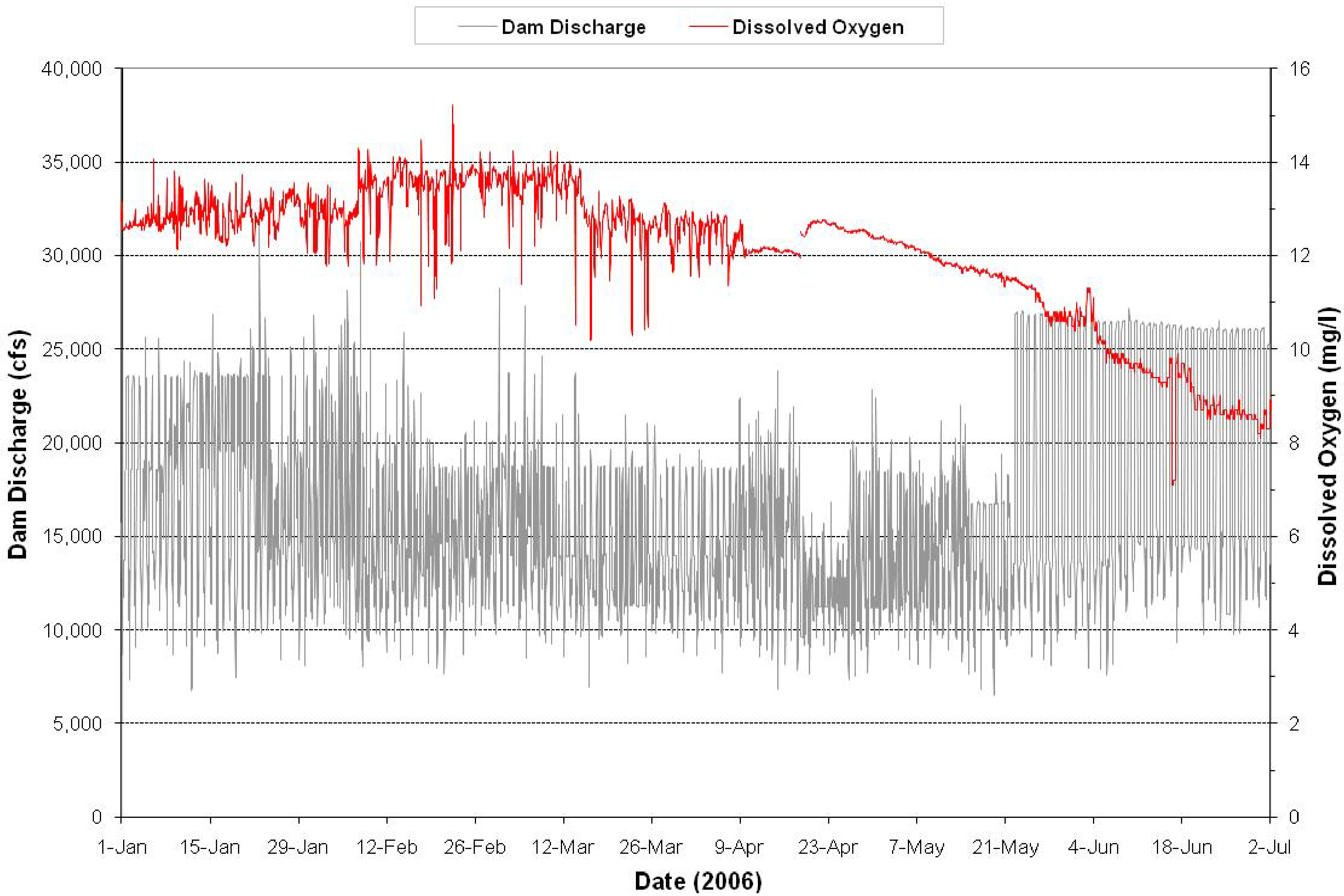

Plate 131. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2006.

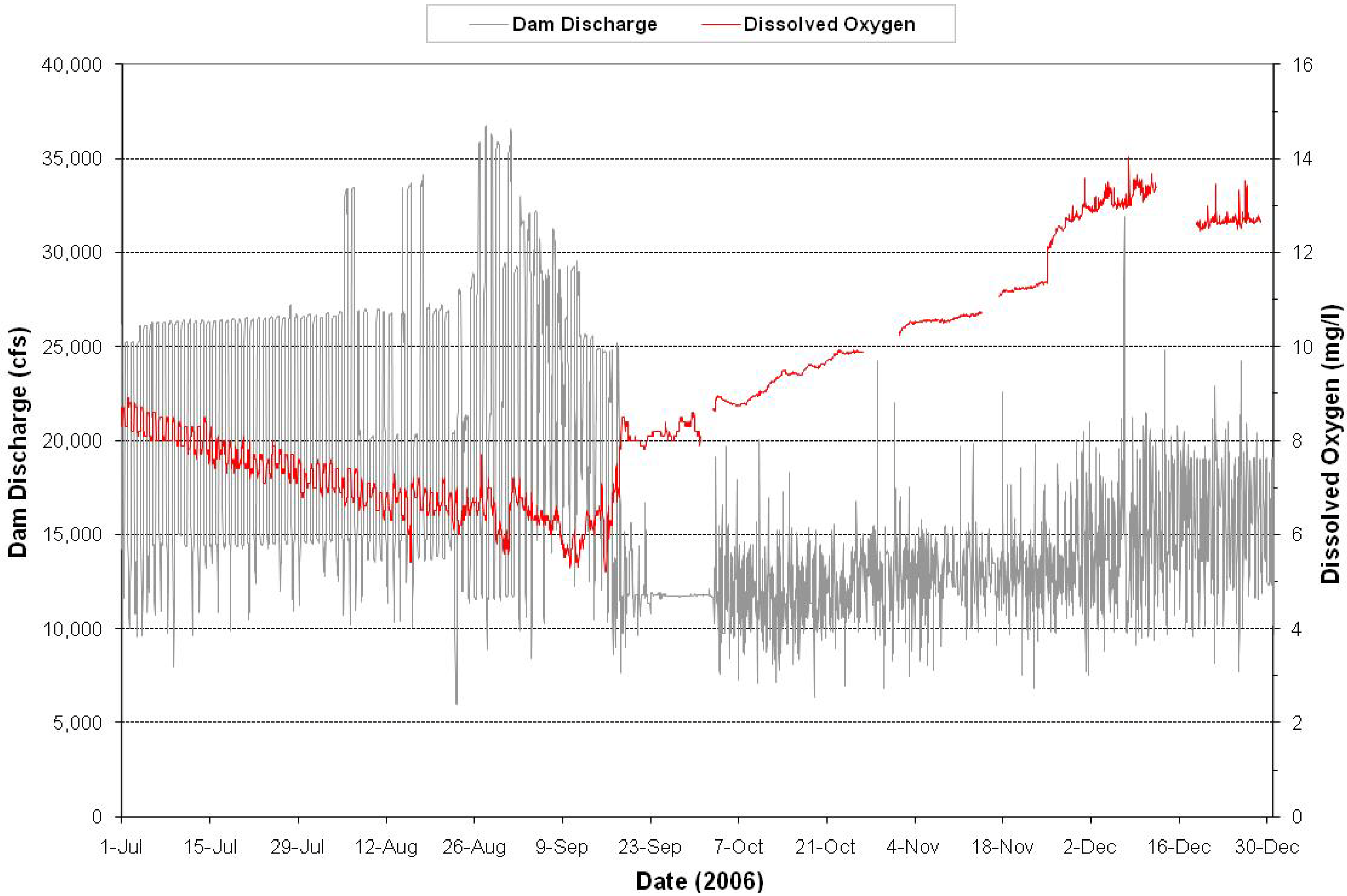

Plate 132. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2006.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

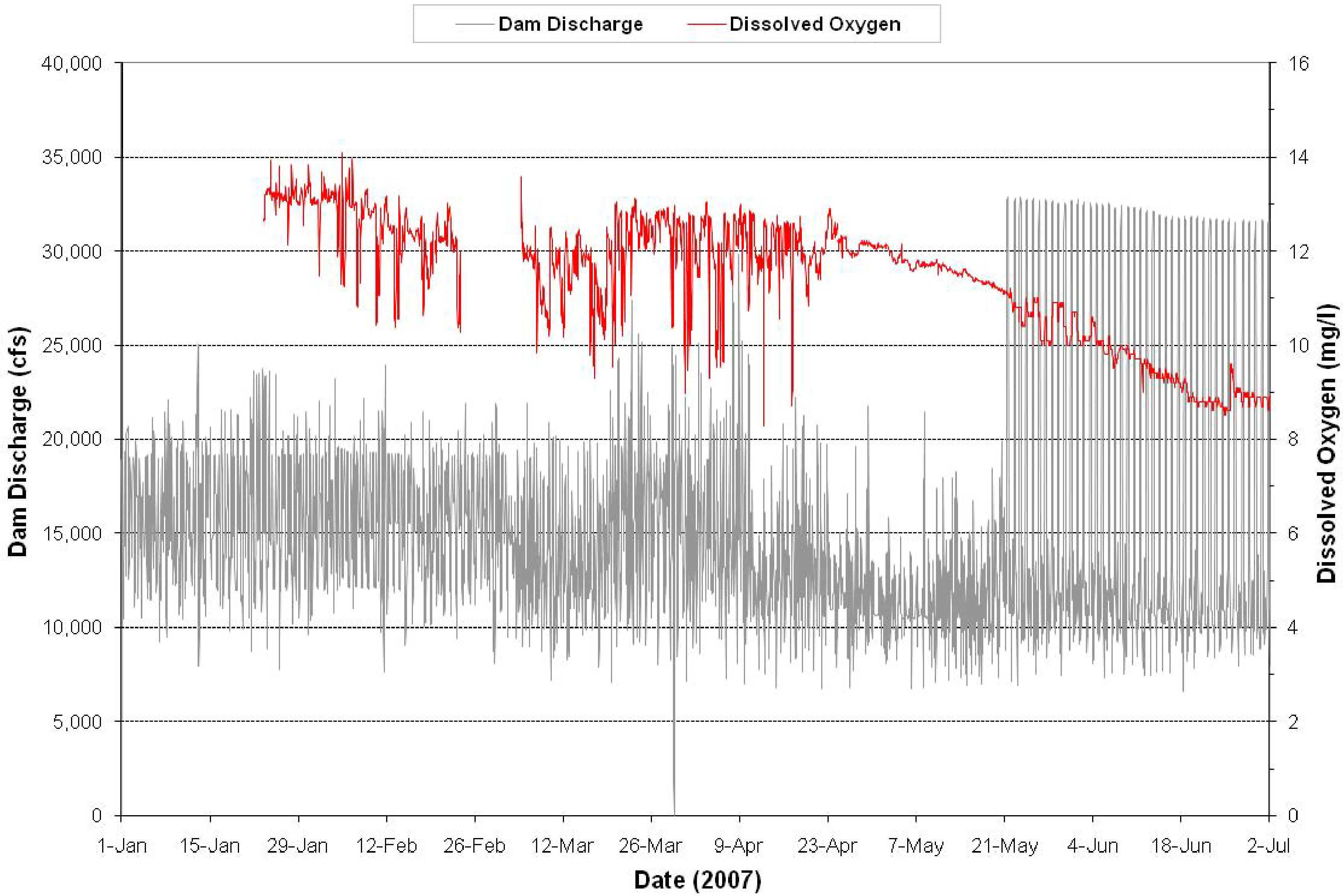

Plate 133. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2007.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

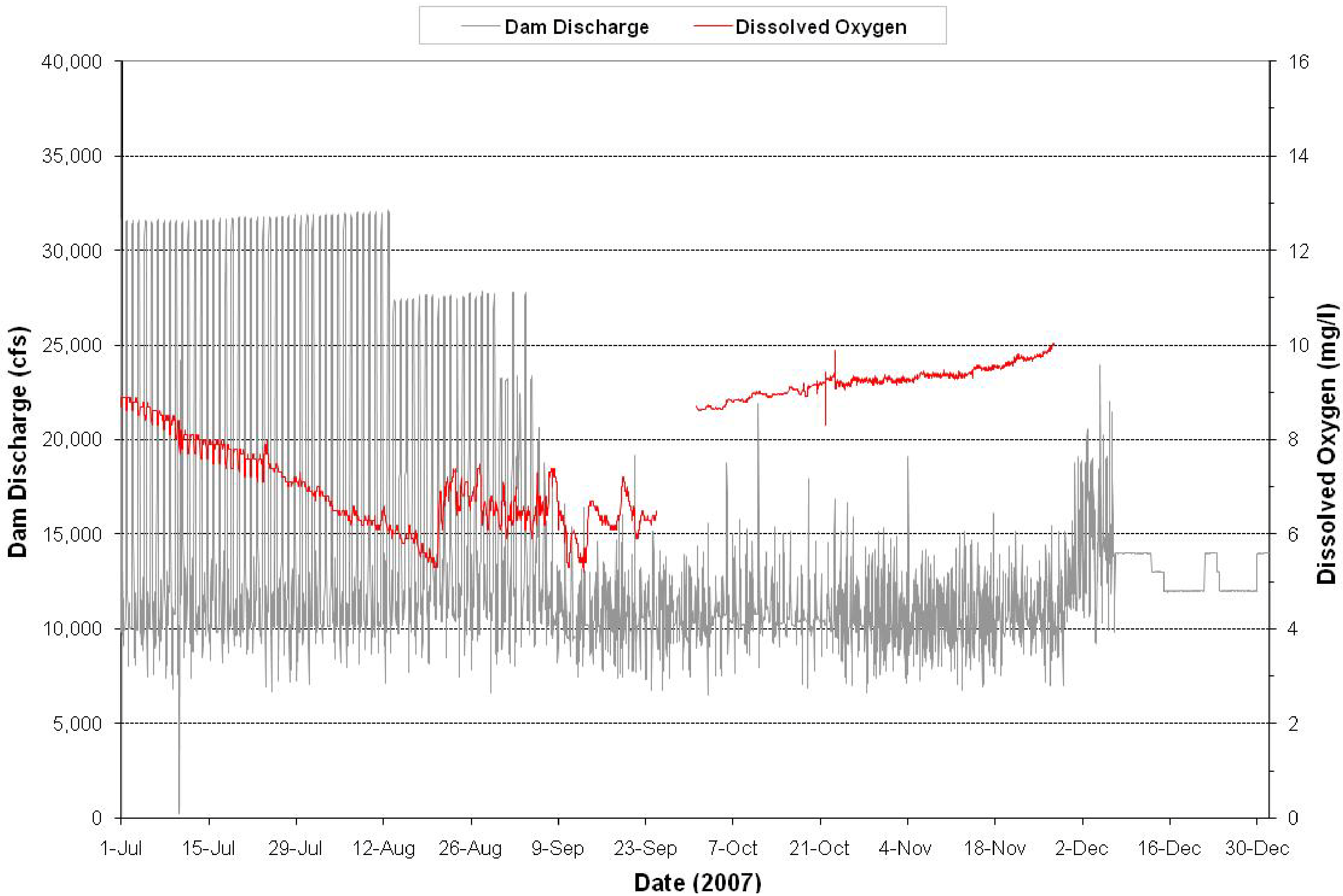

Plate 134. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

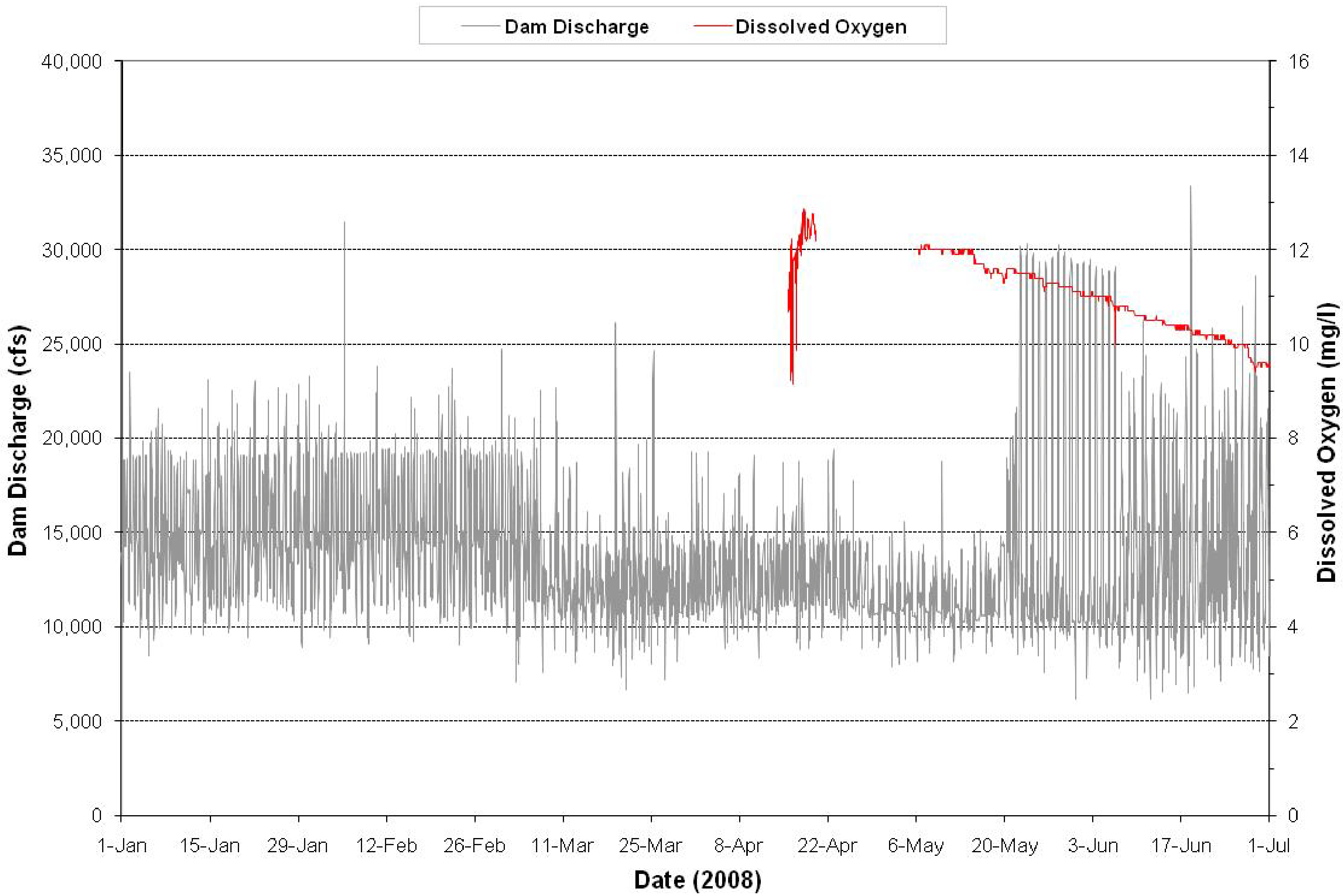

Plate 135. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2008.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

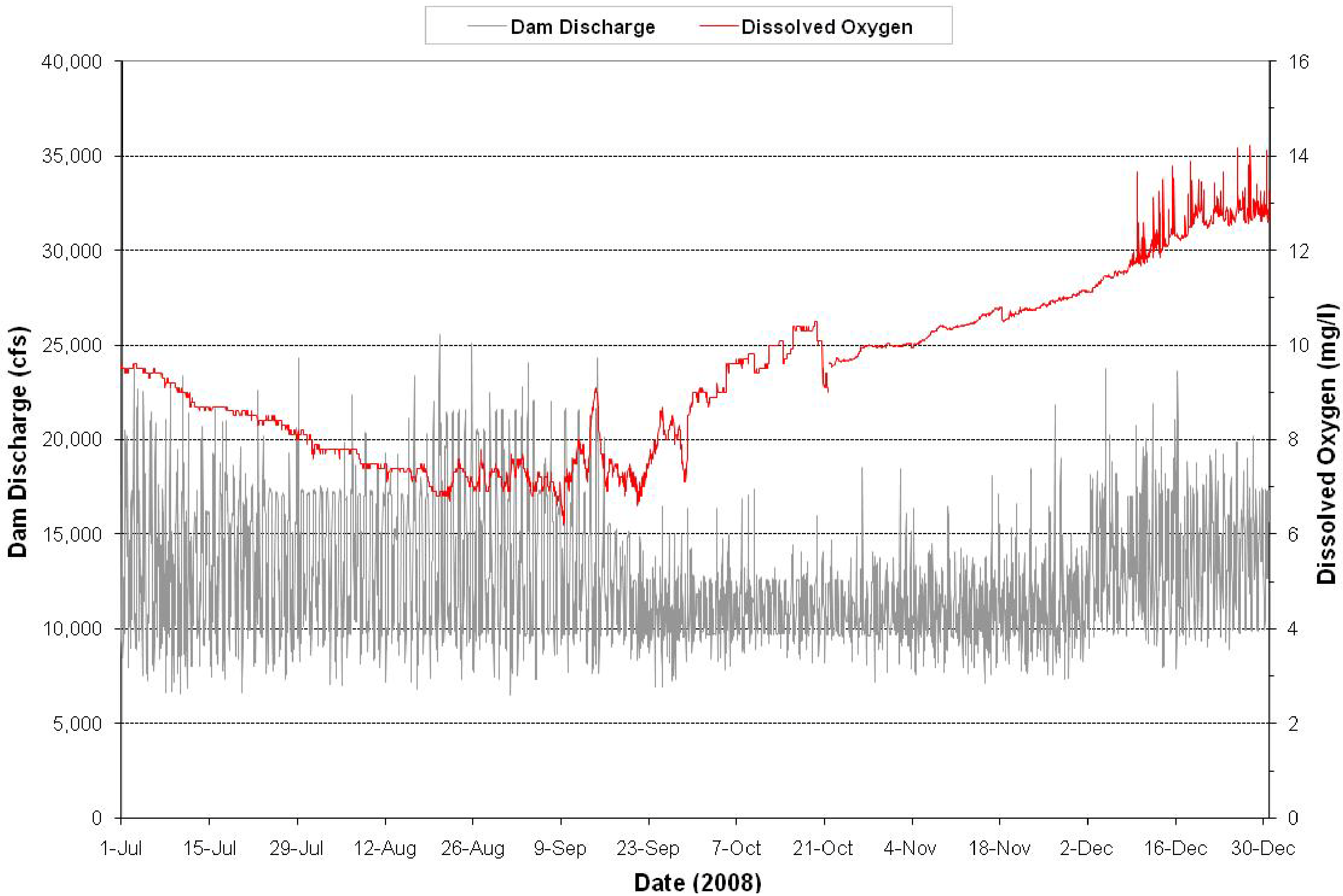

Plate 136. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2008.

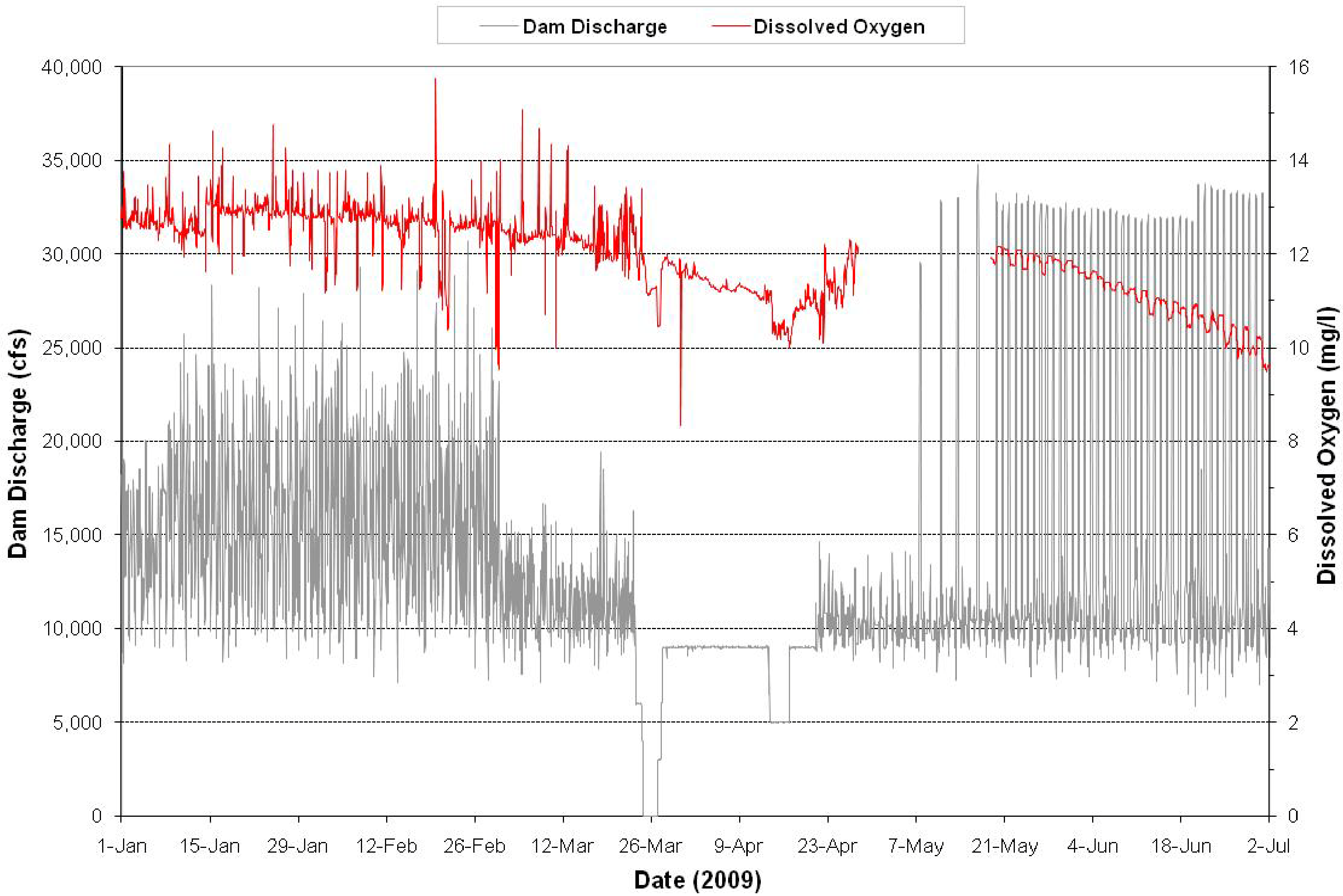

Plate 137. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2009.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

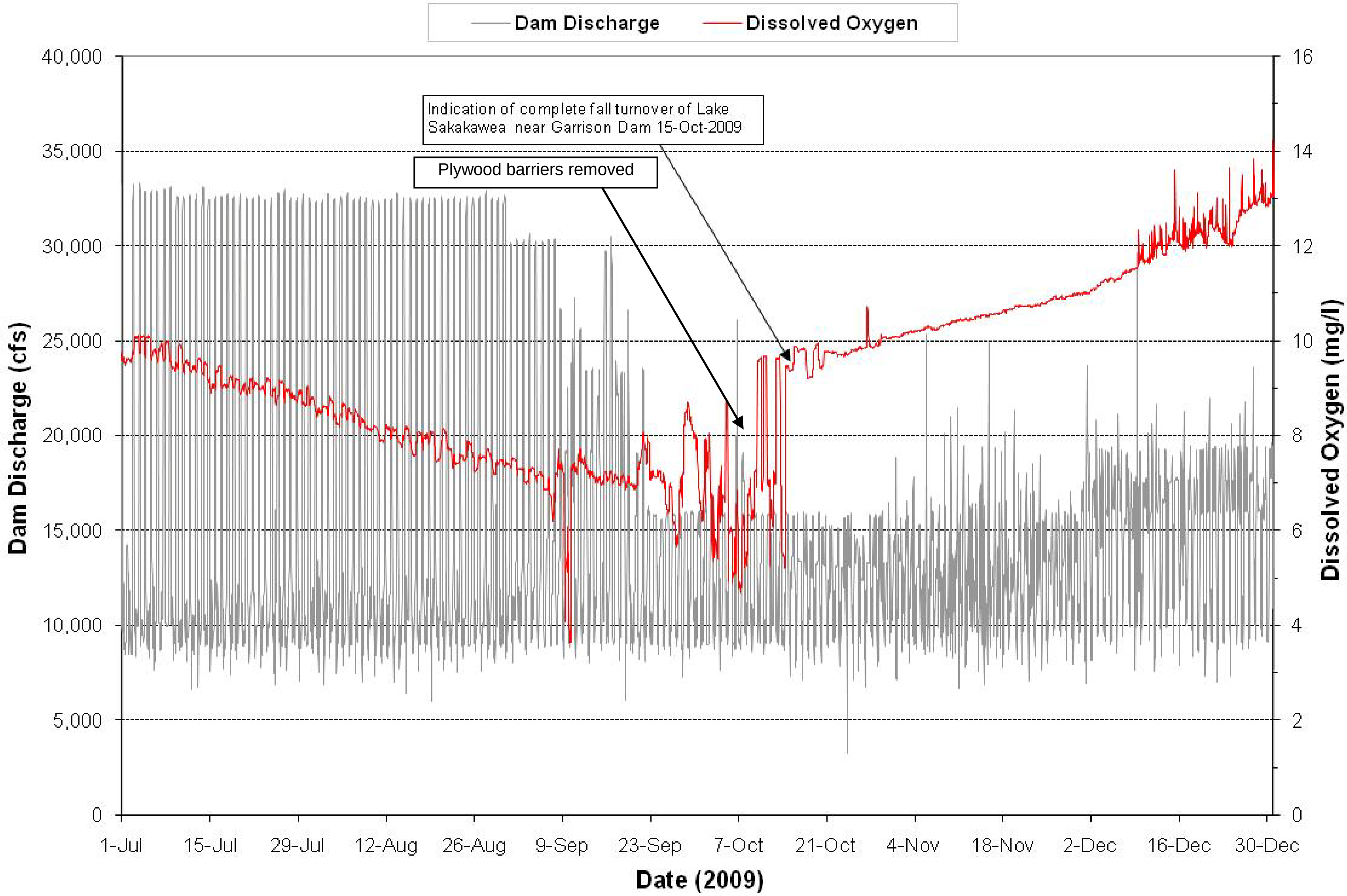

Plate 138. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2009.

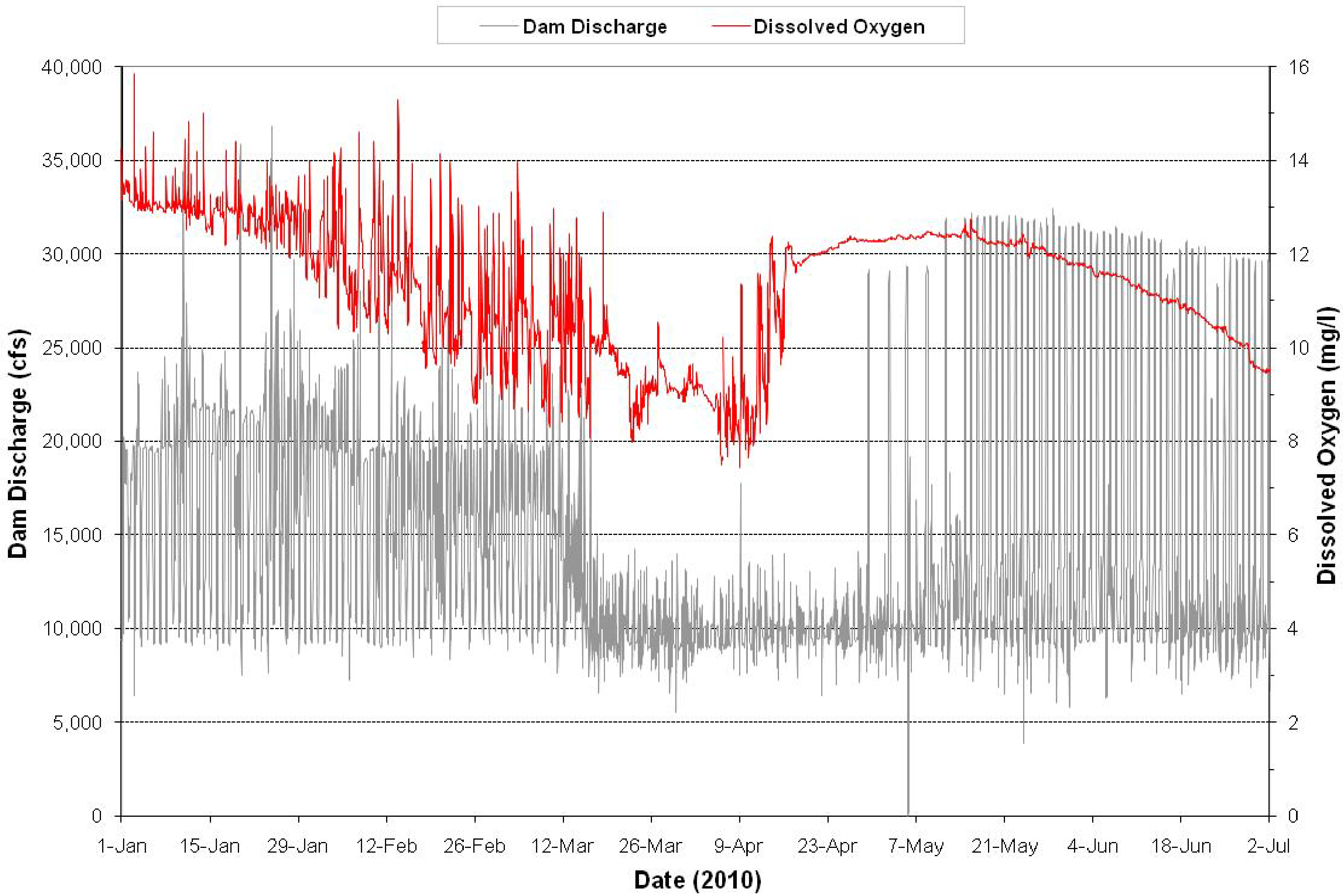

Plate 139. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2010.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

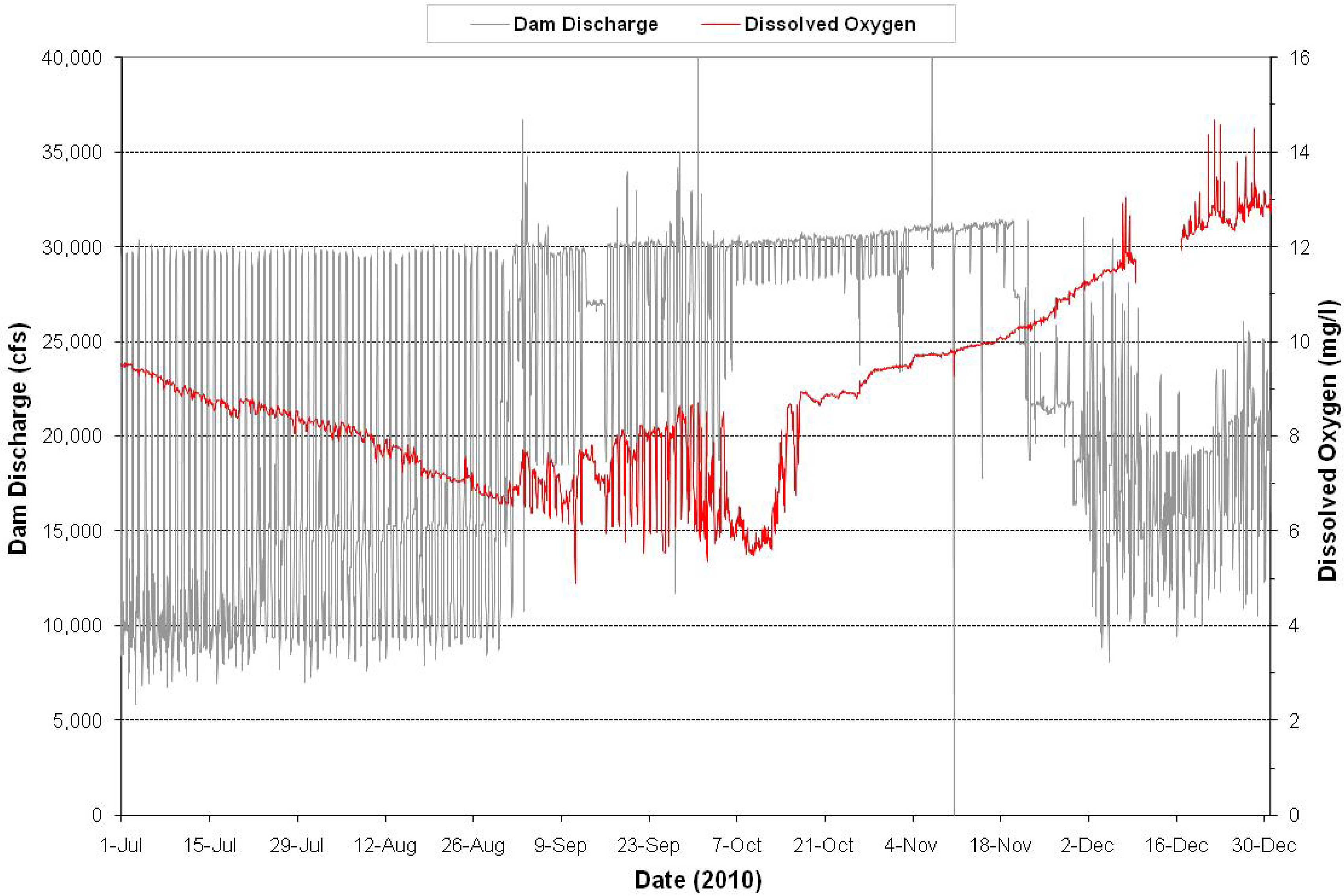

Plate 140. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2010.

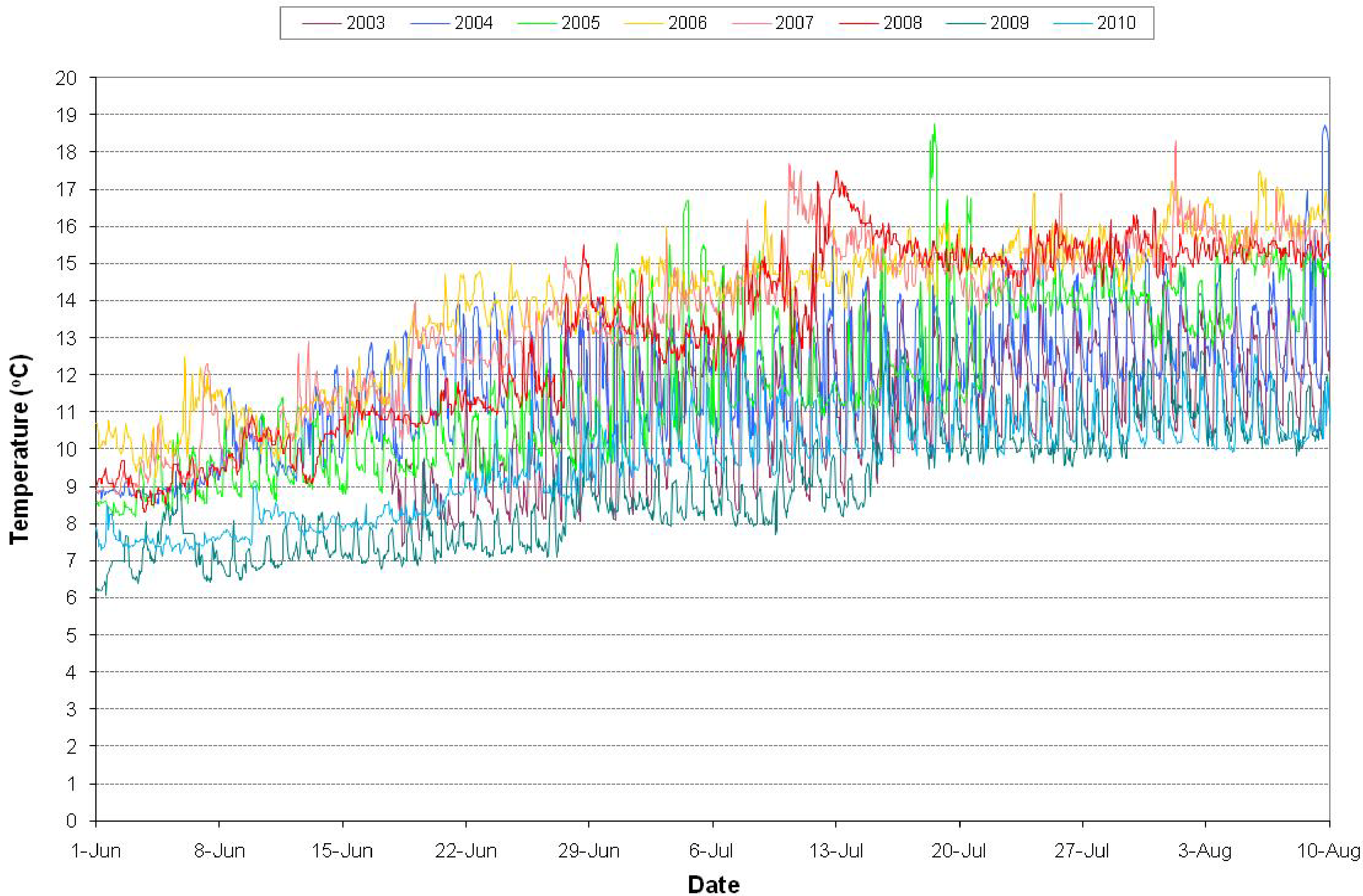

Plate 141. Hourly temperature of water discharged through Garrison Dam during the period June 1 through Mid-August in 2003, 2004, 2005, 2006, 2007, 2008, 2009, and 2010.

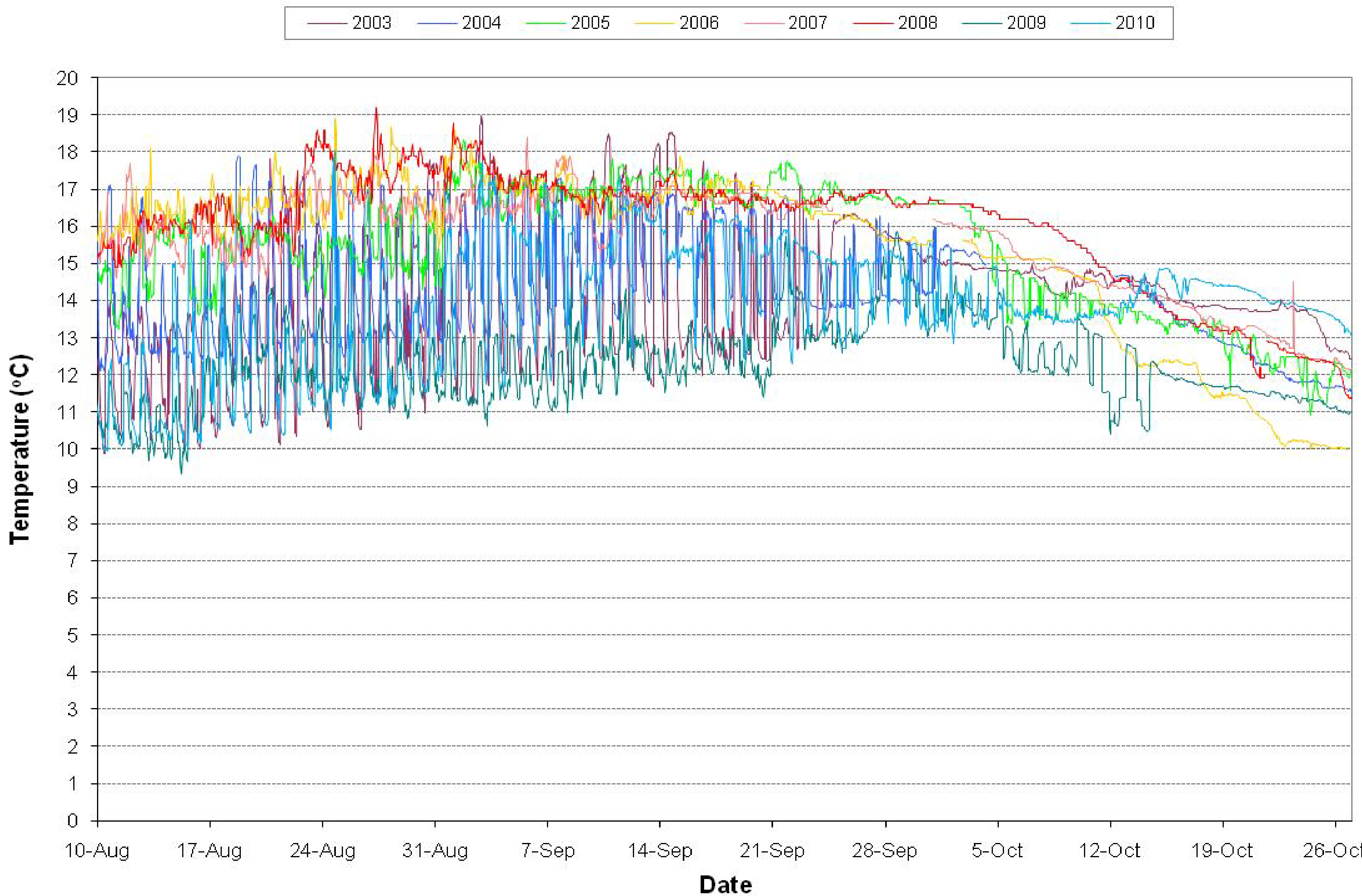

Plate 142. Hourly temperature of water discharged through Garrison Dam during the period Mid-August through October in 2003, 2004, 2005, 2006, 2007, 2008, 2009, and 2010.

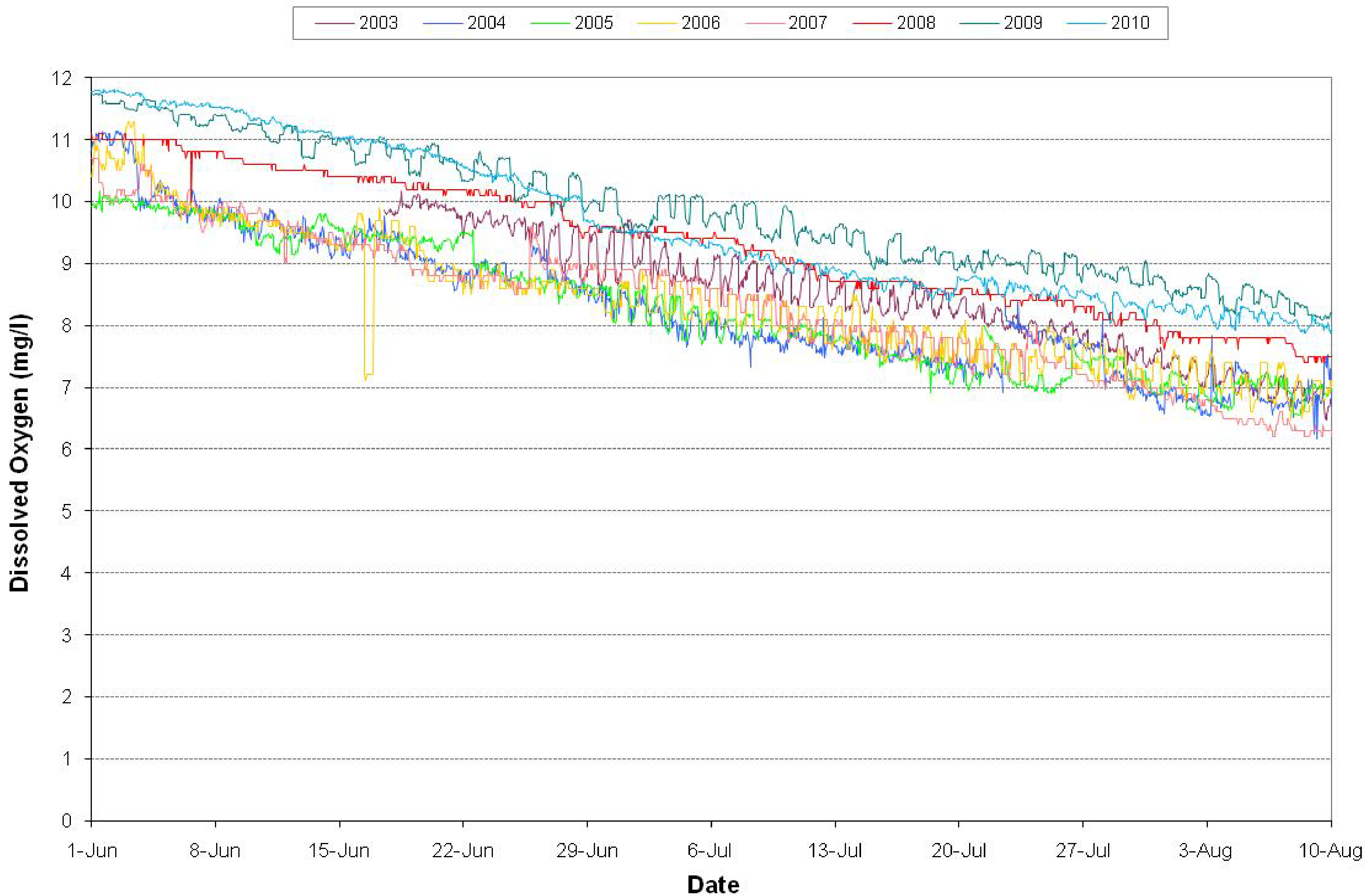

Plate 143. Hourly **d**issolved oxygen concentrations of water discharged through Garrison Dam during the period June through mid-August in 2003, 2004, 2005, 2006, 2007, 2008, 2009, and 2010.

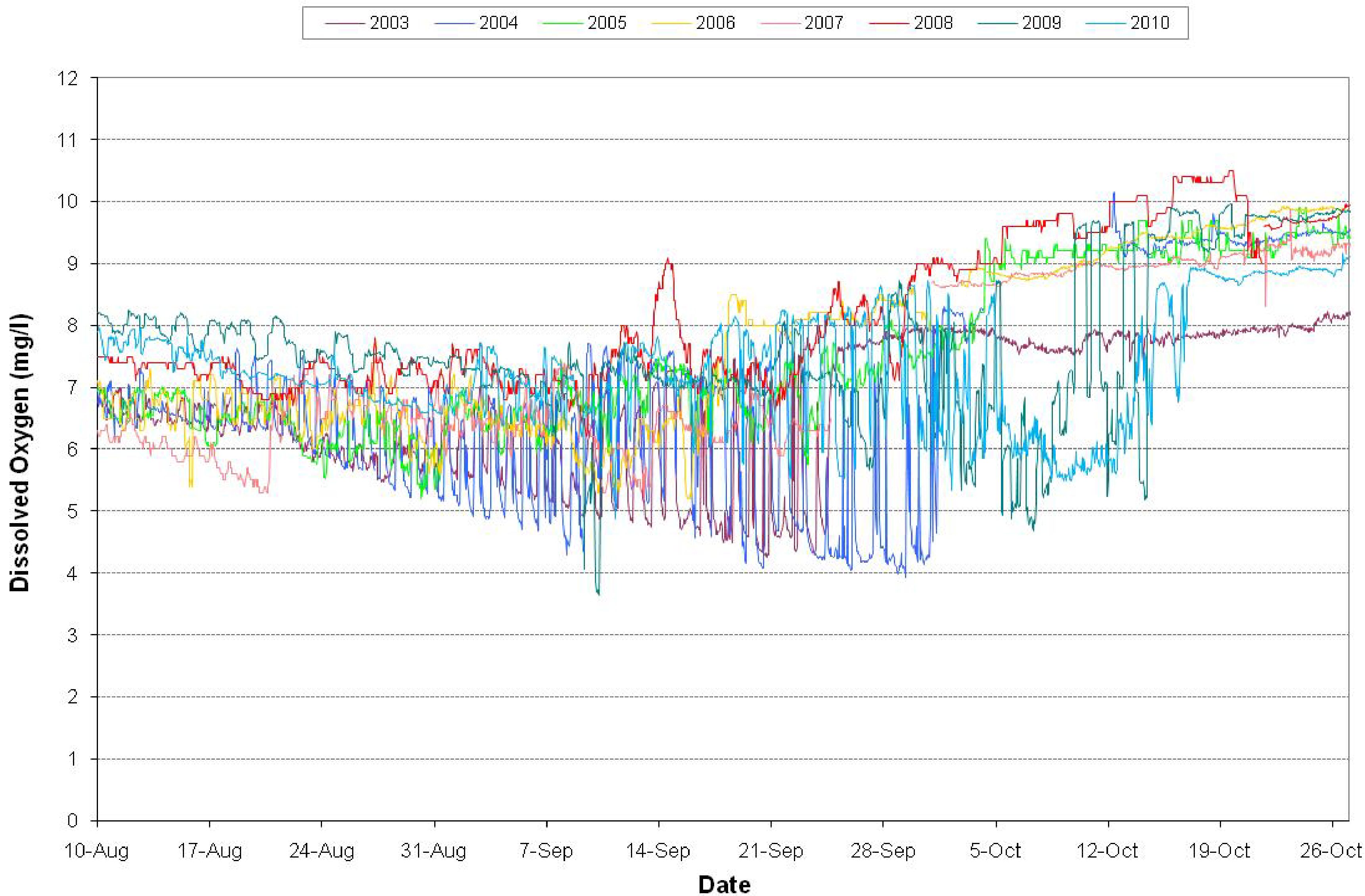

Plate 144. Hourly dissolved oxygen concentrations of water discharged through Garrison Dam during the period mid-August through October in 2003, 2004, 2005, 2006, 2007, 2008, 2009.

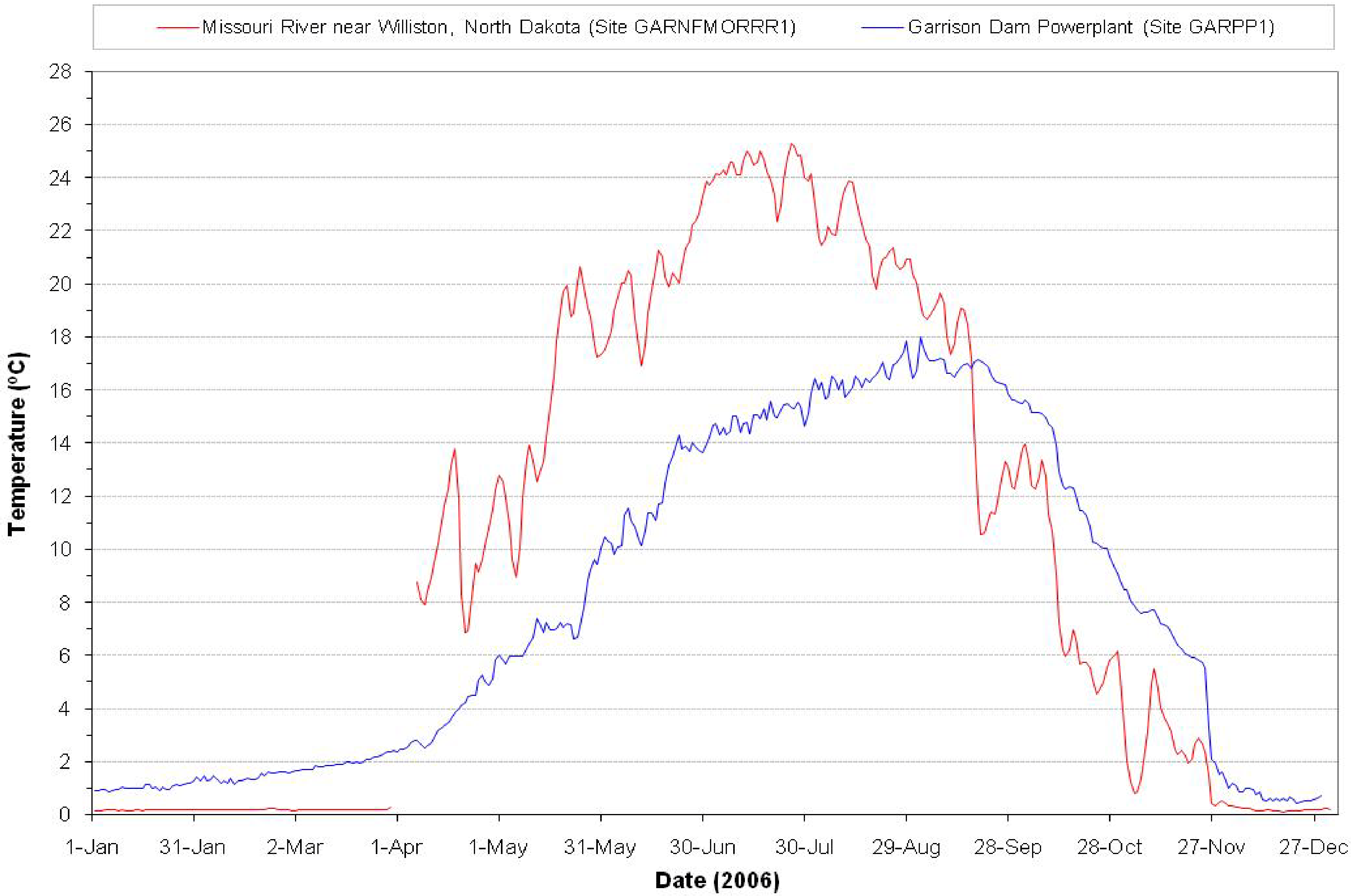

Plate 145. Mean daily water temperatures monitored at the Garrison Powerplant (i.e., site GARPP1) and the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) during 2006.

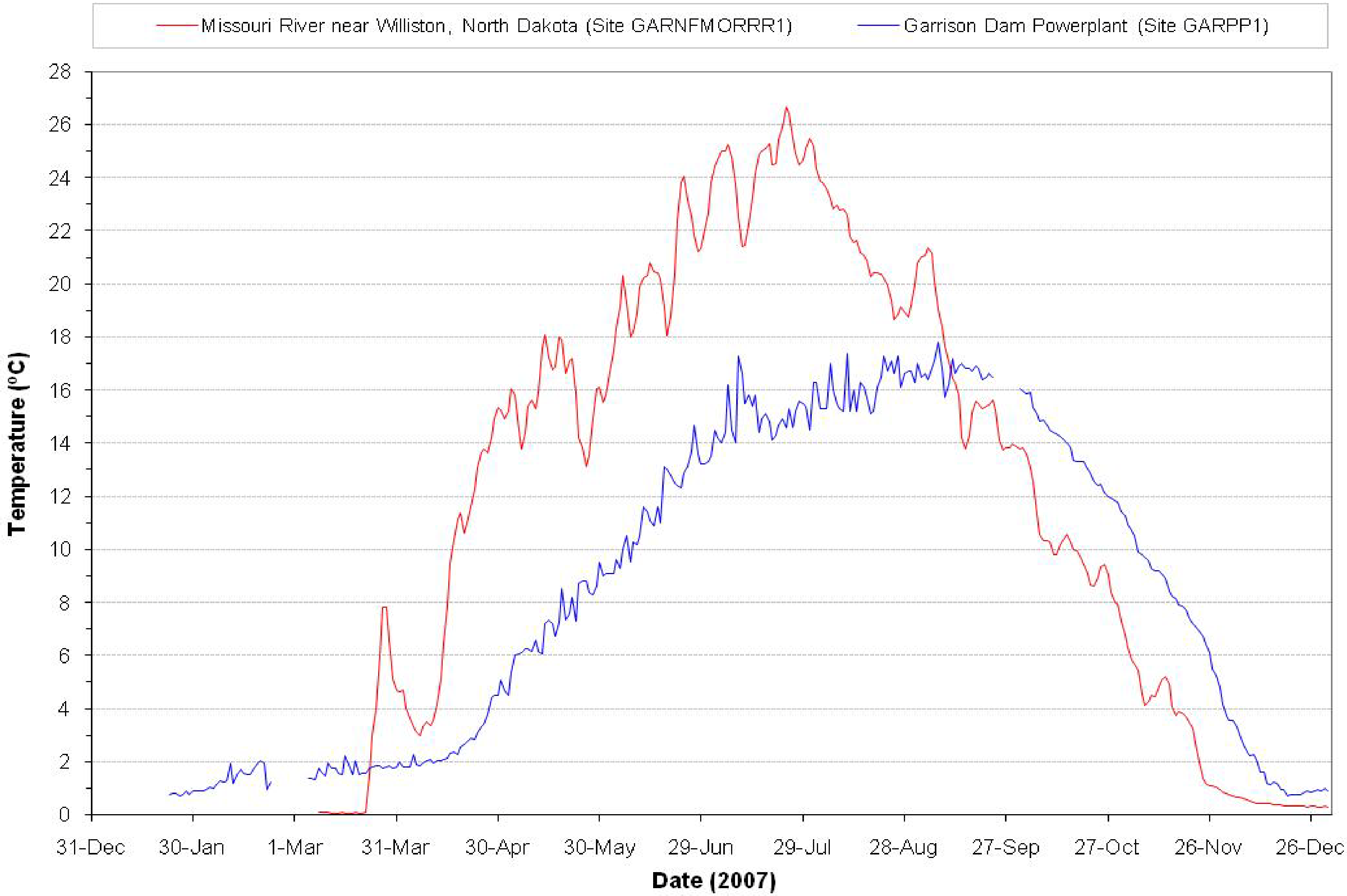

Plate 146. Mean daily water temperatures monitored at the Garrison Powerplant (i.e., site GARPP1) and the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) during 2007.

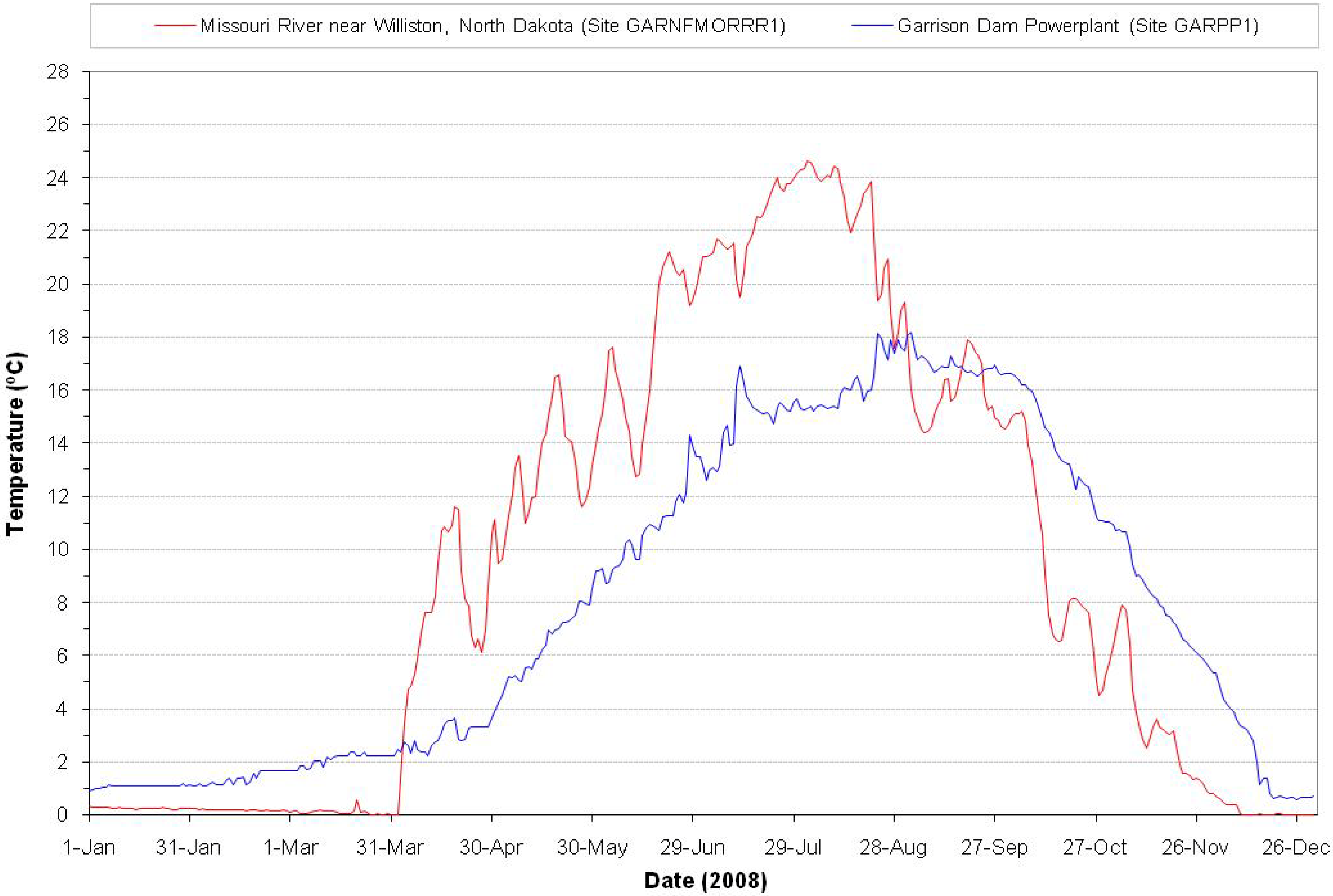

Plate 147. Mean daily water temperatures monitored at the Garrison Powerplant (i.e., site GARPP1) and the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) during 2008.

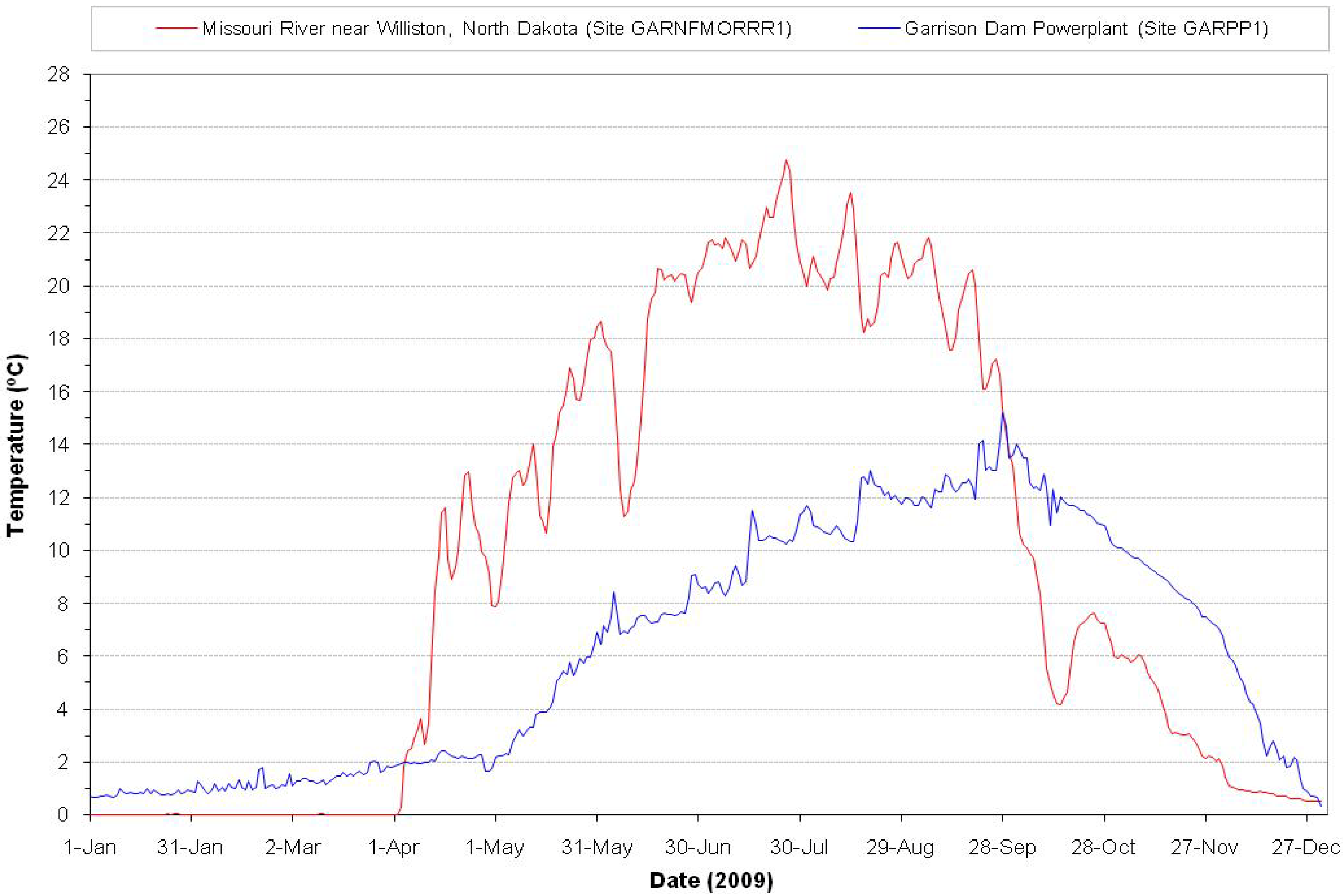

Plate 148. Mean daily water temperatures monitored at the Garrison Powerplant (i.e., site GARPP1) and the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) during 2009.

Plate 149. Mean daily water temperatures monitored at the Garrison Powerplant (i.e., site GARPP1) and the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) during 2010.

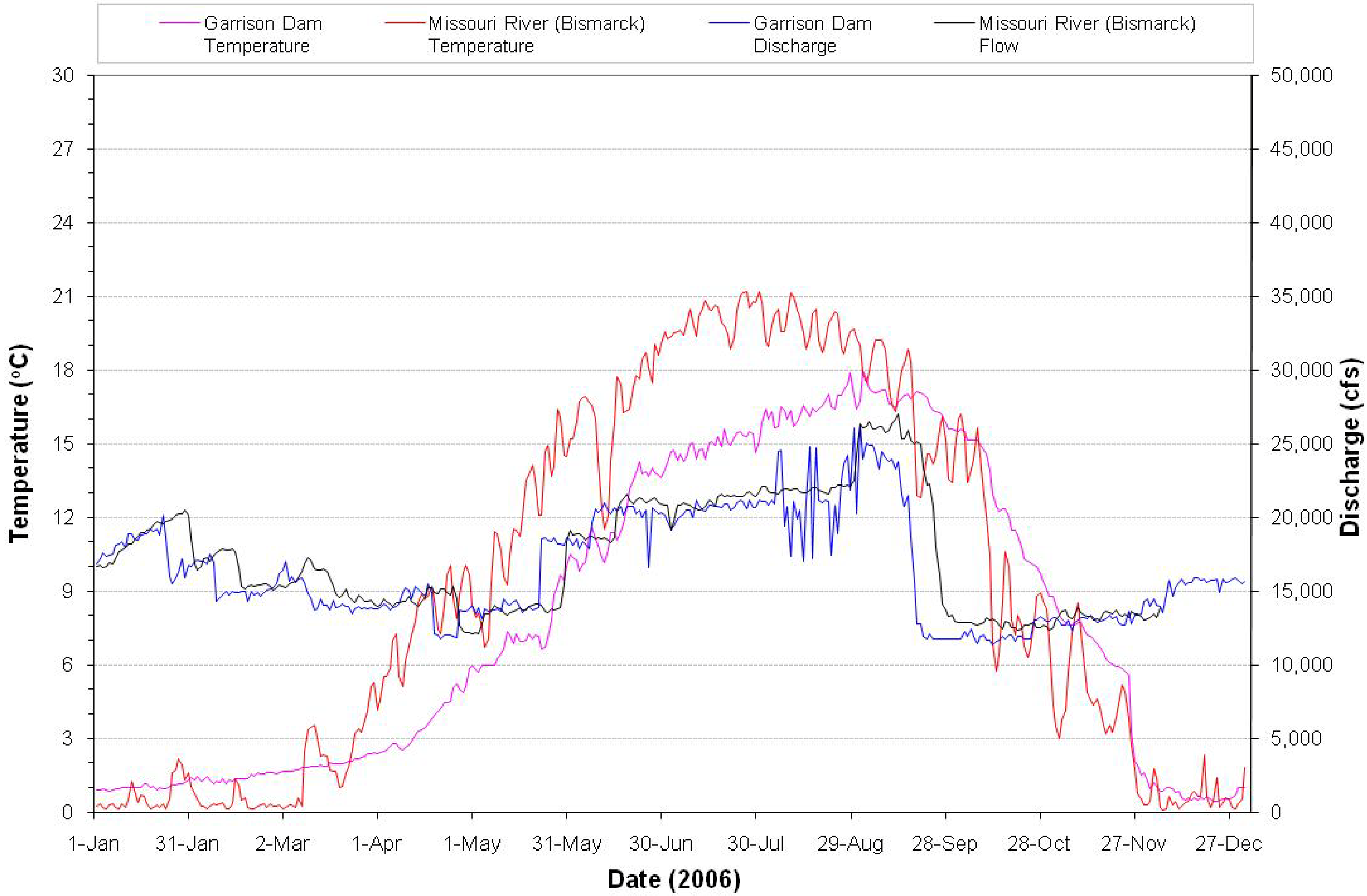

Plate 150. Mean daily water temperature and discharge for the Garrison Dam discharge and Missouri River at Bismarck, North Dakota for 2006. (Daily means based on hourly measurements.)

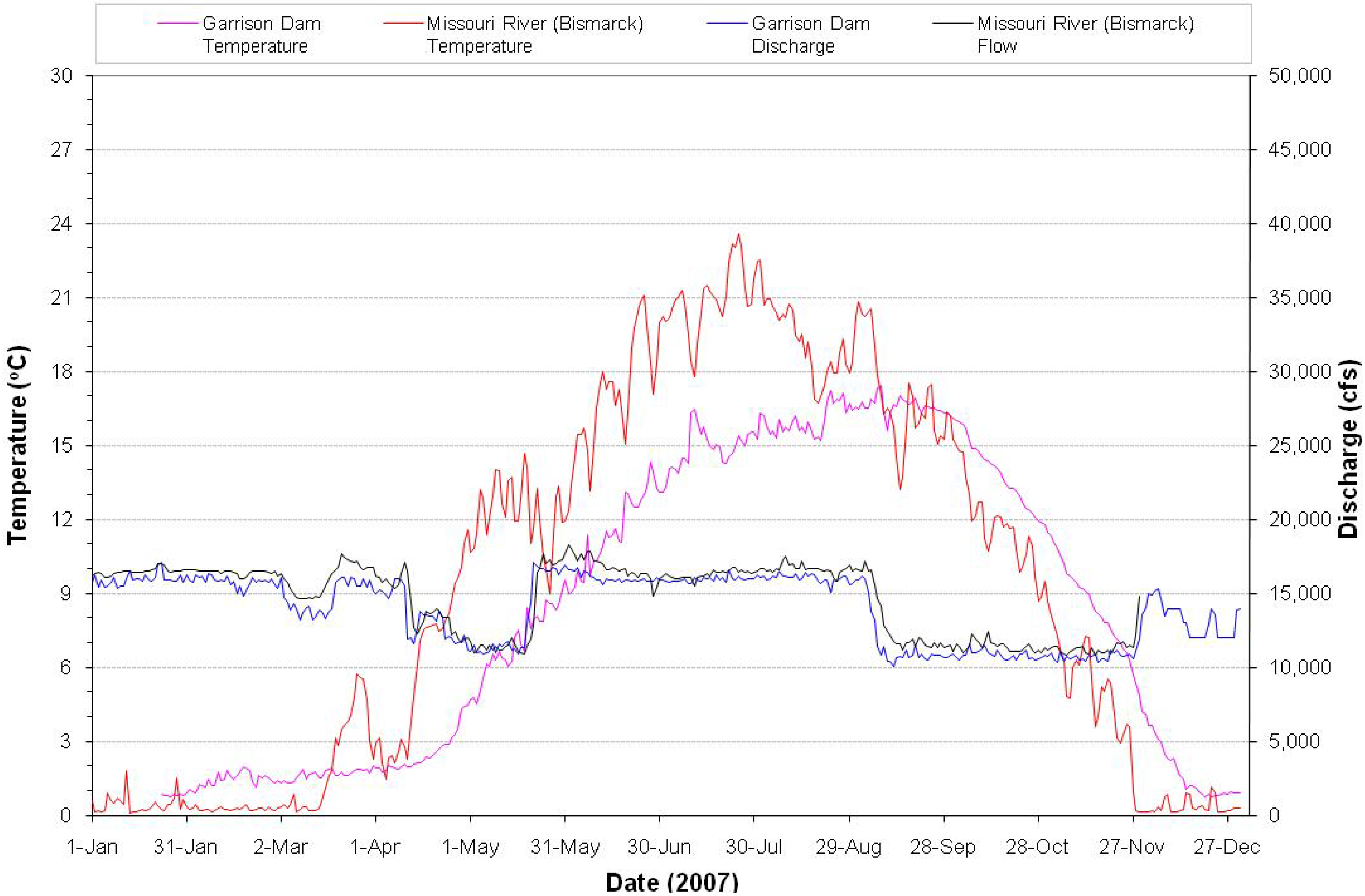

Plate 151. Mean daily water temperature and discharge for the Garrison Dam discharge and Missouri River at Bismarck, North Dakota for 2007. (Daily means based on hourly measurements.)

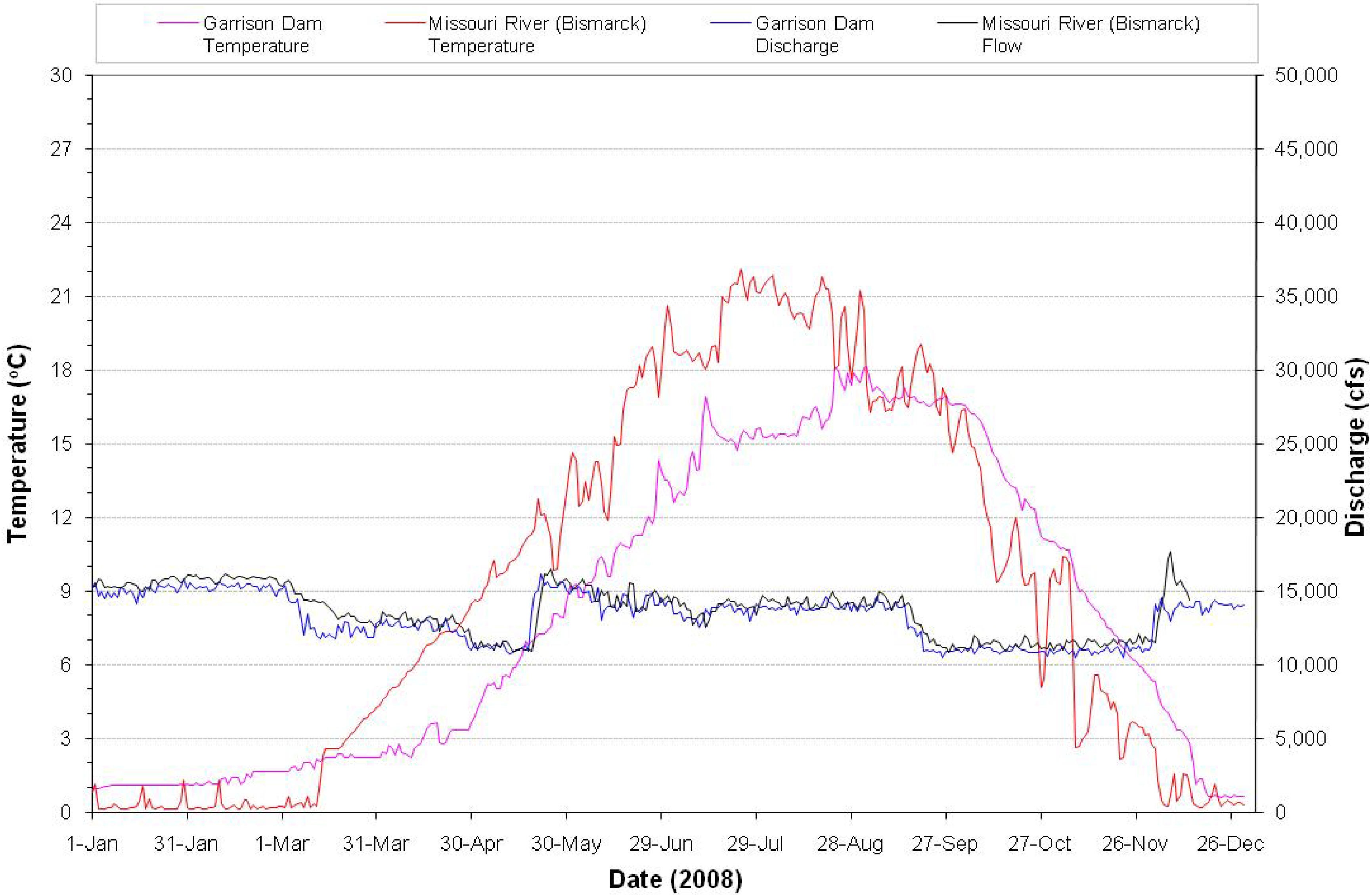

Plate 152. Mean daily water temperature and discharge for the Garrison Dam discharge and Missouri River at Bismarck, North Dakota for 2008. (Daily means based on hourly measurements.)

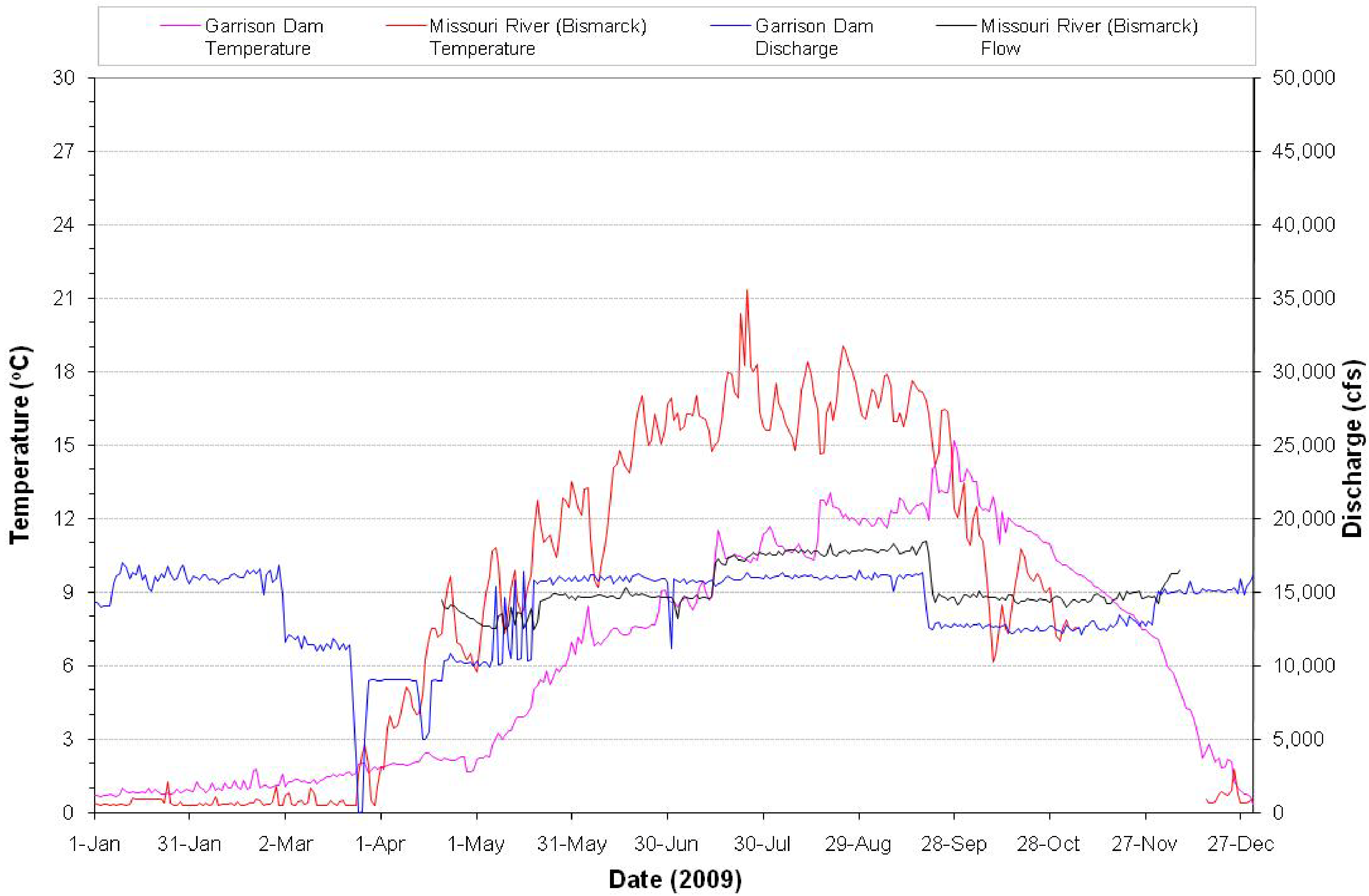

Plate 153. Mean daily water temperature and discharge for the Garrison Dam discharge and Missouri River at Bismarck, North Dakota for 2009. (Daily means based on hourly measurements.)

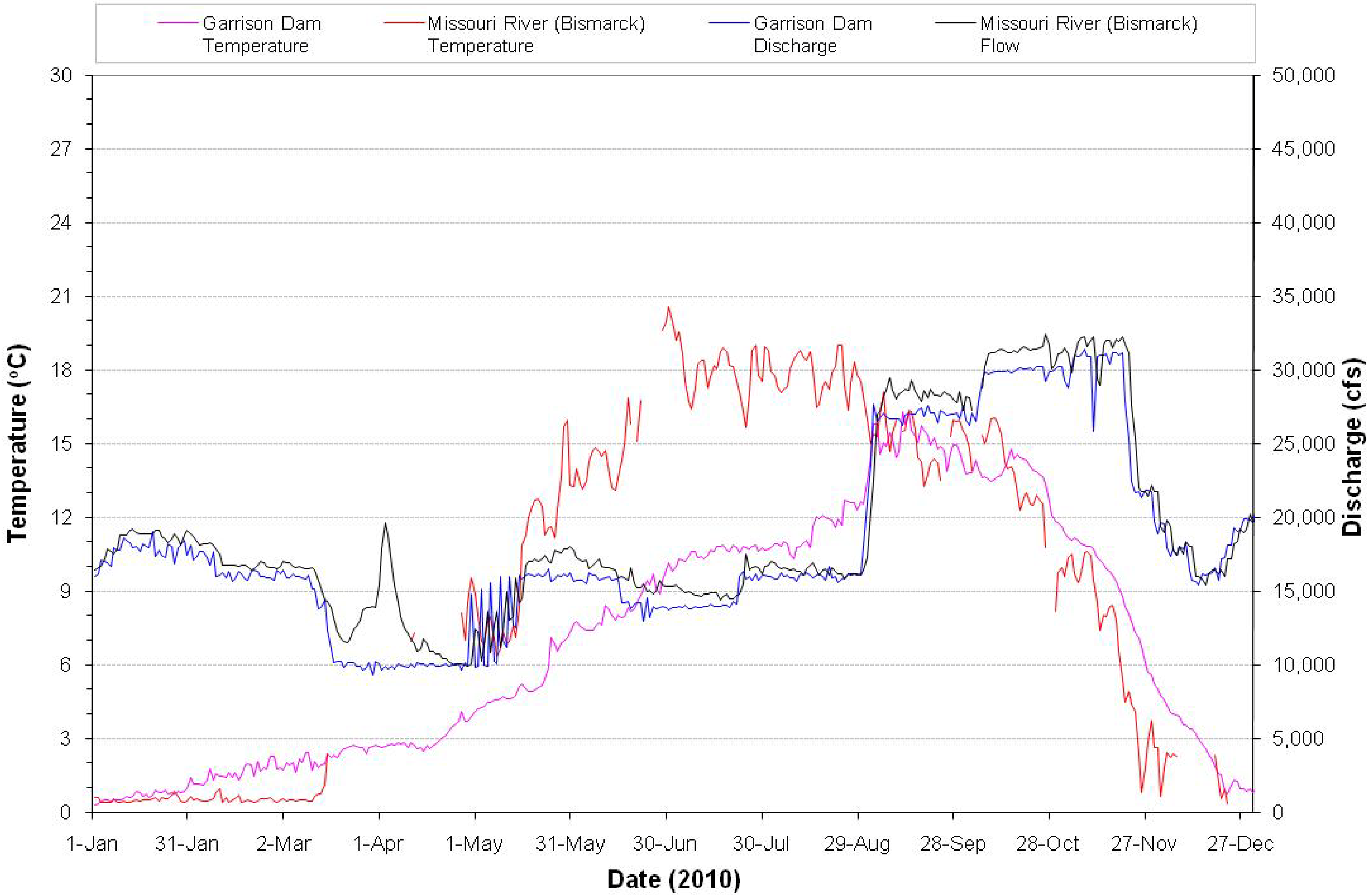

Plate 154. Mean daily water temperature and discharge for the Garrison Dam discharge and Missouri River at Bismarck, North Dakota for 2010. (Daily means based on hourly measurements.)

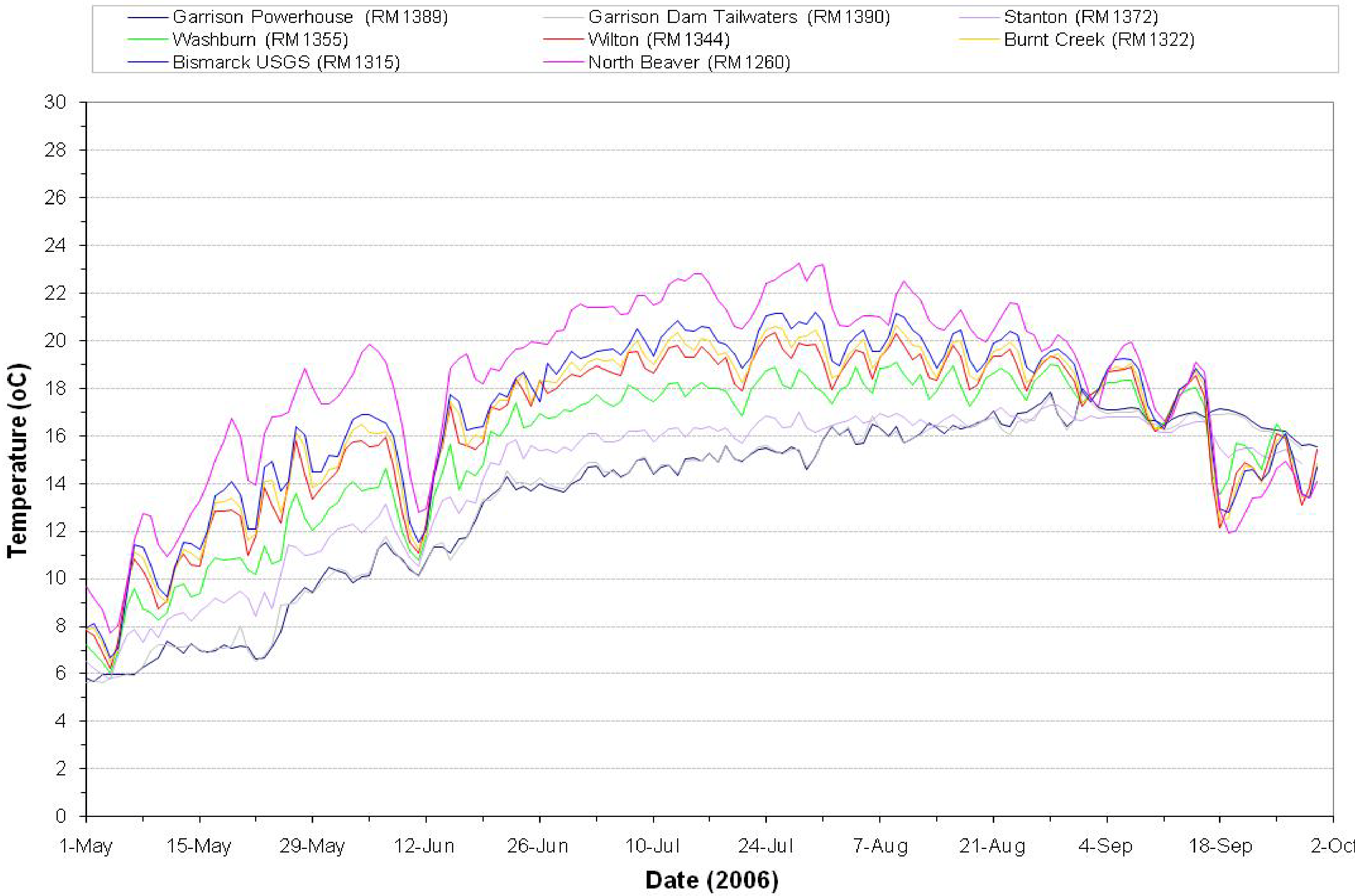

Plate 155. Mean daily water temperatures monitored in the Missouri River from Garrison Dam to Beaver Bay for the period May through September 2006.

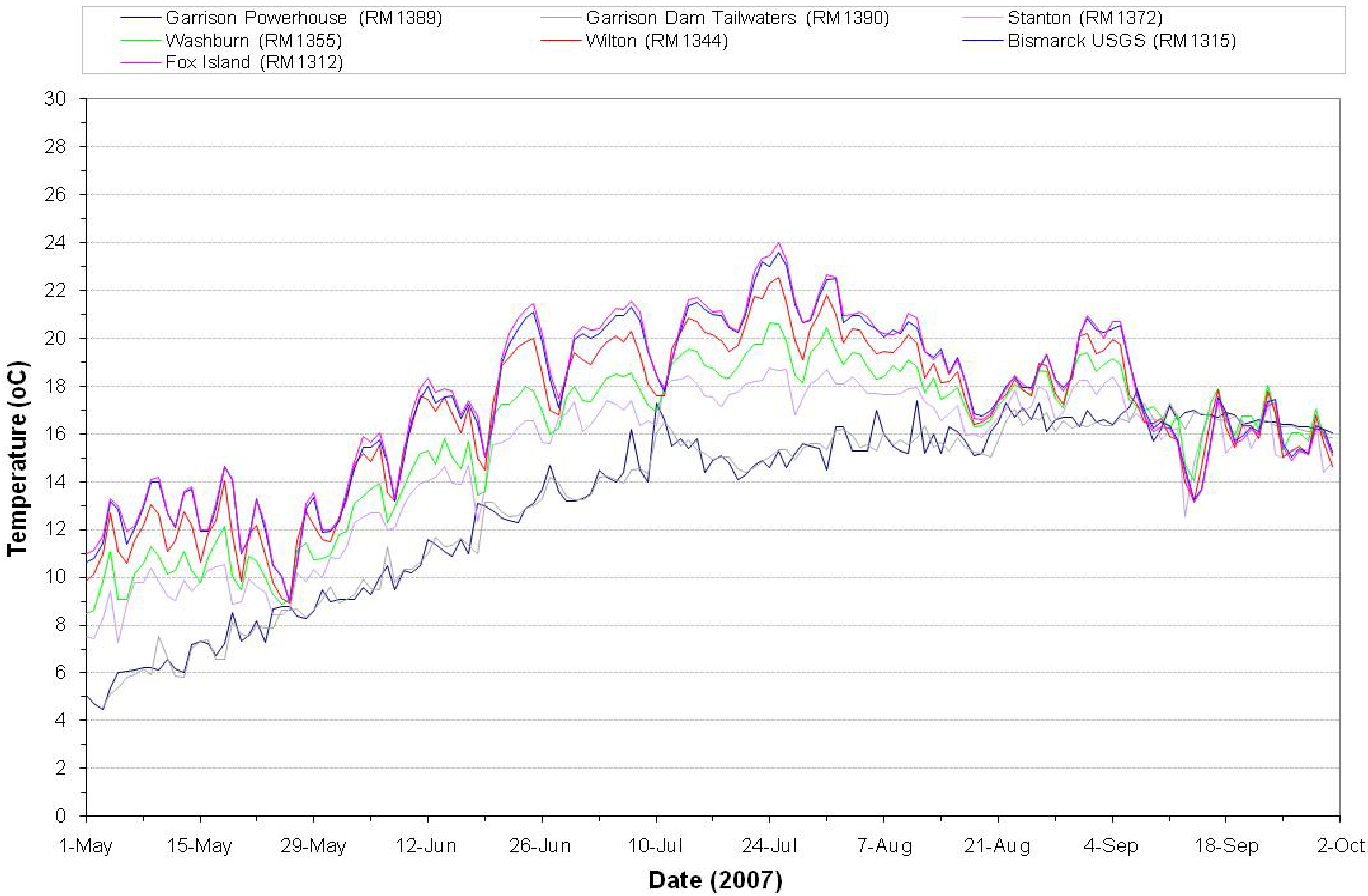

Plate 156. Mean daily water temperatures monitored in the Missouri River from Garrison Dam to Fox Island for the period May through September 2007.

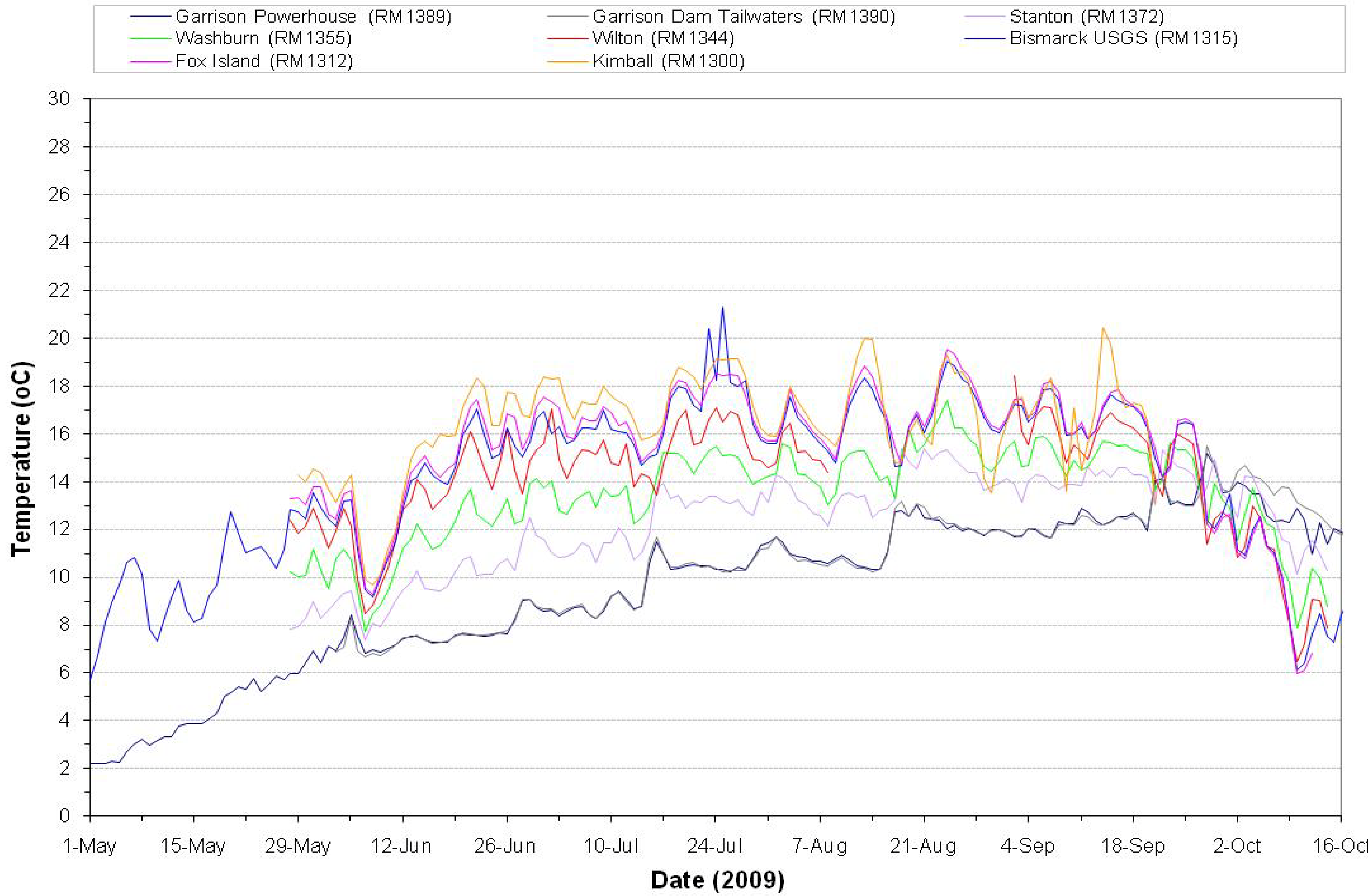

Plate 157. Mean daily water temperatures monitored in the Missouri River from Garrison Dam to Fox Island for the period May through mid-October 2009.

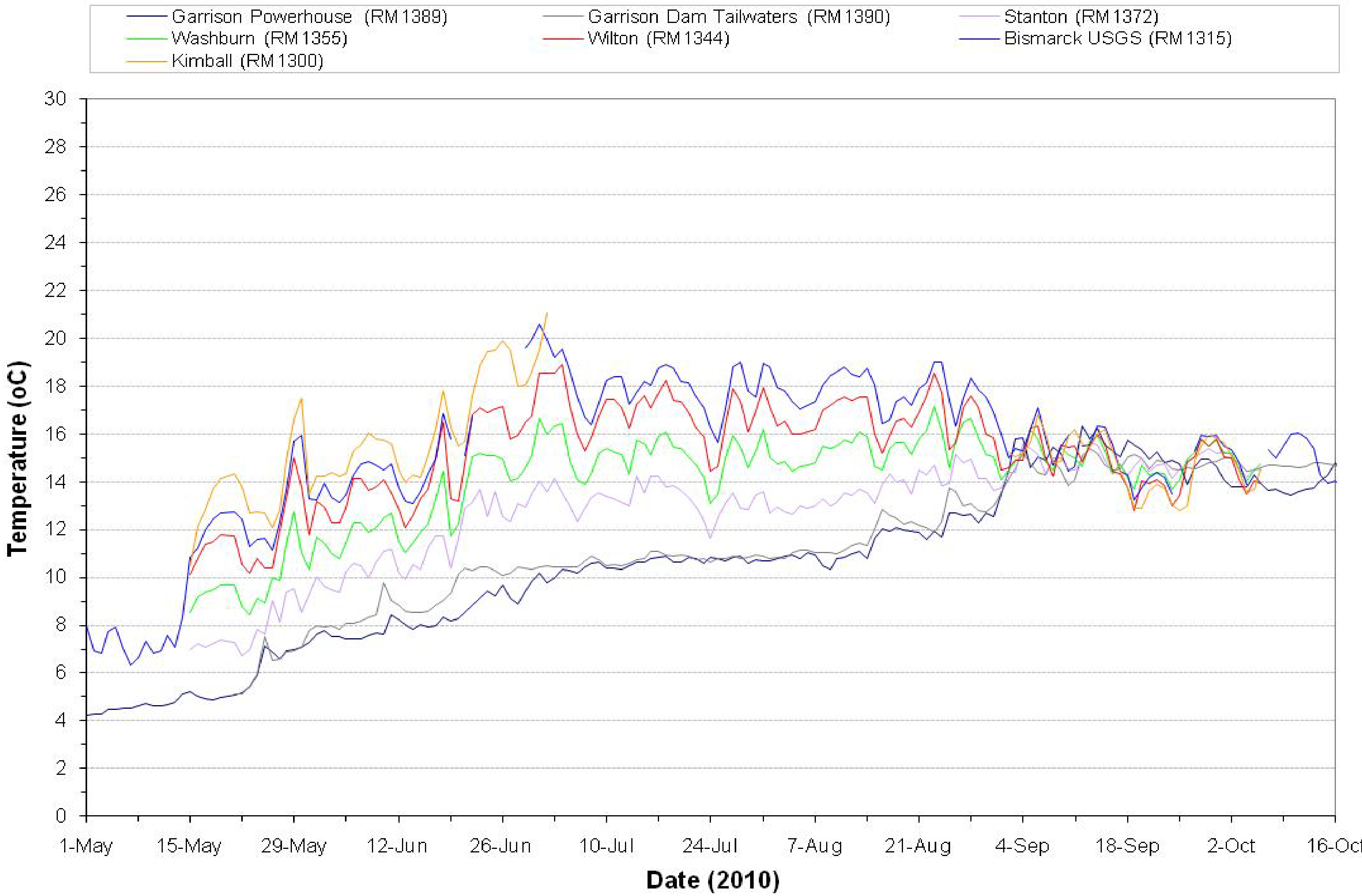

Plate 158. Mean daily water temperatures monitored in the Missouri River from Garrison Dam to Kimball for the period May through mid-October 2010.

Plate 159. Summary of monthly (May through September) water quality conditions monitored in Lake Oahe near Oahe Dam (Site OAHLK1073A) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	25	1594.8	1592.6	1570.9	1617.5	-----	-----	-----
Water Temperature (°C)	0.1	1,207	12.4	10.6	5.1	25.6	18.3(1,5)	234	19%
Hypolimnion Water Temperature (°C)[E]	0.1	442	9.2	9.0	6.1	15.1	18.3(1,5)	0	0%
Dissolved Oxygen (mg/l)	0.1	1,207	9.2	8.9	6.2	12.3	6(1,6,8), 7(1,6,8)	0, 68	0%, 6%
Dissolved Oxygen (% Sat.)	0.1	1,207	88.8	92.2	58.2	111.0	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	709	9.3	8.9	6.3	12.3	5(3,6)	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	441	8.8	8.7	6.2	11.4	6(1,6,8)	0	0%
Specific Conductance (umhos/cm)	1	1,206	702	700	615	758	-----	-----	-----
pH (S.U.)	0.1	1,161	8.2	8.2	7.2	9.1	6.5(1,2,6), 9.0(1,2,5), 9.5(4,5)	0, 9, 0	0%, 1%, 0%
Turbidity (NTUs)	1	1,204	-----	n.d.	n.d.	48	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	1,165	352	352	208	473	-----	-----	-----
Secchi Depth (in.)	1	24	160	160	76	248	-----	-----	-----
Alkalinity, Total (mg/l)	7	46	158	160	140	190	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	44	3.4	3.1	1.6	6.1	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	46	9	9	n.d.	20	-----	-----	-----
Chloride (mg/l)	1	37	11	11	9	13	175(1,5), 100(1,7), 438(2,5), 250(2,7)	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	896	4	3	n.d.	18	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	24	4	3	n.d.	16	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	46	486	462	372	842	1,750(2,5), 1,000(2,7), 3,500(4,5), 2,000(4,7)	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	46	-----	n.d.	n.d.	0.17	3.8 (1,5,9), 1.7 (1,7,9)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	46	0.5	0.4	n.d.	2.3	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	46	-----	0.03	n.d.	0.30	10(2,5)	0	0%
Nitrogen, Total (mg/l)	0.1	46	0.5	0.4	n.d.	2.3	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	47	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	46	0.03	0.03	n.d.	0.14	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	46	-----	n.d.	n.d.	0.05	-----	-----	-----
Sulfate (mg/l)	1	46	200	205	163	223	875(2,5), 500(2,7)	0	0%
Suspended Solids, Total (mg/l)	4	46	-----	n.d.	n.d.	9	53(1,5), 30(1,7)	0	0%
Microcystin, Total (ug/l)	0.2	24	-----	n.d.	n.d.	n.d.	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	25	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	0	0%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

Plate 160. Summary of monthly (May through September) water quality conditions monitored in Lake Oahe near the confluence of the Cheyenne River (Site OAHLK1110DW) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results[(A)]						Water Quality Standards Attainment		
	Detection Limit[(B)]	No. of Obs.	Mean[(C)]	Median	Min.	Max.	State WQS Criteria[(D)]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	23	1596.2	1593.6	1570.9	1617.5	-----	-----	-----
Water Temperature (°C)	0.1	848	15.1	14.4	5.9	25.5	18.3[(1,5)]	296	35%
Hypolimnion Water Temperature (°C)[(E)]	0.1	246	11.2	11.3	7.6	15.4	18.3[(1,5)]	0	0%
Dissolved Oxygen (mg/l)	0.1	848	8.5	8.3	5.1	11.8	6[(1,6,8)], 7[(1,6,8)]	43, 148	5%, 17%
Dissolved Oxygen (% Sat.)	0.1	848	87.3	92.7	46.3	113.3	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[(E)]	0.1	561	8.8	8.4	5.4	11.8	5[(3,6)]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[(E)]	0.1	245	7.5	7.1	5.1	10.1	6[(1,6,8)]	38	16%
Specific Conductance (umhos/cm)	1	848	706	698	605	1,224	-----	-----	-----
pH (S.U.)	0.1	814	8.2	8.3	7.2	3.0	6.5[(1,2,6)], 9.0[(1,2,5)], 9.5[(4,5)]	0	0%
Turbidity (NTUs)	1	845	-----	1	n.d.	20	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	848	352	355	203	466	-----	-----	-----
Secchi Depth (in.)	1	23	120	110	56	275	-----	-----	-----
Alkalinity, Total (mg/l)	7	46	154	153	133	180	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	44	3.5	3.3	1.3	6.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	46	11	11	n.d.	25	-----	-----	-----
Chloride (mg/l)	1	36	10	11	8	13	175[(1,5)], 100[(1,7)], 438[(2,5)], 250[(2,7)]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	685	6	4	n.d.	66	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	23	5	3	n.d.	15	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	45	491	466	308	756	1,750[(2,5)], 1,000[(2,7)], 3,500[(4,5)], 2,000[(4,7)]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	46	-----	n.d.	n.d.	0.27	3.8 [(1,5,9)], 1.7 [(1,7,9)]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	46	0.5	0.4	n.d.	2.5	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	45	-----	0.04	n.d.	0.40	10[(2,5)]	0	0%
Nitrogen, Total (mg/l)	0.1	45	0.5	0.4	n.d.	2.5	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	46	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	46	0.03	0.03	n.d.	0.12	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	46	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	46	202	201	148	367	875[(2,5)], 500[(2,7)]	0	0%
Suspended Solids, Total (mg/l)	4	45	-----	n.d.	n.d.	13	53[(1,5)], 30[(1,7)]	0	0%
Microcystin, Total (ug/l)	0.2	23	-----	n.d.	n.d.	0.2	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[(F)]	-----	23	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	2	9%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

Plate 161. Summary of monthly (June through September) water quality conditions monitored in Lake Oahe near Whitlocks Bay (Site OAHLK1153DW) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	23	1596.2	1593.6	1571.1	1617.1	-----	-----	-----
Water Temperature (°C)	0.1	699	15.6	16.5	6.0	25.3	18.3[1,5]	277	40%
Hypolimnion Water Temperature (°C)[E]	0.1	210	12.4	12.1	8.3	19.9	18.3[1,5]	7	3%
Dissolved Oxygen (mg/l)	0.1	693	8.0	7.9	2.5	12.0	6[1,6,8], 7[1,6,8]	108, 146	16%, 21%
Dissolved Oxygen (% Sat.)	0.1	693	82.6	88.4	27.0	107.0	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	451	8.3	8.1	3.5	11.3	5[3,6]	8	2%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	210	6.7	7.2	2.5	9.8	6[1,6,8]	82	39%
Specific Conductance (umhos/cm)	1	697	627	639	443	711	-----	-----	-----
pH (S.U.)	0.1	699	8.1	8.3	7.0	9.0	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	698	3	2	n.d.	24	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	699	362	363	209	516	-----	-----	-----
Secchi Depth (in.)	1	23	90	88	41	156	-----	-----	-----
Alkalinity, Total (mg/l)	7	46	149	152	103	180	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	44	3.6	3.5	1.6	6.9	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	45	12	12	2	23	-----	-----	-----
Chloride (mg/l)	1	36	9	9	6	11	175[1,5], 100[1,7], 438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	573	5	5	n.d.	18	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	23	6	7	1	14	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	46	446	431	312	684	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	46	-----	0.03	n.d.	0.24	3.1 [1,5,9], 1.2 [1,7,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	46	0.6	0.5	n.d.	2.5	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	46	-----	0.04	n.d.	0.40	10[2,5]	0	0%
Nitrogen, Total (mg/l)	0.1	46	0.7	0.6	n.d.	2.5	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	46	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	46	0.05	0.04	n.d.	0.23	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	46	-----	0.02	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	46	164	162	111	207	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	46	-----	n.d.	n.d.	14	53[1,5], 30[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	16	-----	n.d.	n.d.	0.2	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	23	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	6	26%

n.d. = Not detected.

[A] Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

[B] Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

[C] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[D] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for the protection of coldwater permanent fish life propagation waters.
- [2] Criteria for the protection of domestic water supply waters.
- [3] Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- [4] Criteria for the protection of commerce and industry waters.
- [5] Daily maximum criterion (monitoring results directly comparable to criterion).
- [6] Daily minimum criterion (monitoring results directly comparable to criterion).
- [7] 30-day average criterion (monitoring results not directly comparable to criterion).
- [8] The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- [9] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

[E] A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

[F] Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

Plate 162. Summary of monthly (June through September) water quality conditions monitored in Lake Oahe near Mobridge, South Dakota (Site OAHLK1196DW) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	23	1596.2	1593.6	1571.1	1617.1	-----	-----	-----
Water Temperature (°C)	0.1	418	17.8	19.3	7.1	26.4	18.3[1,5]	248	59%
Hypolimnion Water Temperature (°C)[E]	0.1	34	13.1	12.5	10.8	17.8	18.3[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	418	8.0	8.1	1.2	11.5	6[1,6,8], 7[1,6,8]	37, 56	9%, 13%
Dissolved Oxygen (% Sat.)	0.1	418	86.7	90.8	12.4	108.3	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	381	8.2	8.1	1.2	11.5	5[3,6]	12	3%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	33	5.6	7.0	1.2	8.2	6[1,6,8]	15	45%
Specific Conductance (umhos/cm)	1	418	598	633	331	685	-----	-----	-----
pH (S.U.)	0.1	418	8.2	8.3	6.8	8.7	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	417	10	6	n.d.	123	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	418	363	369	126	485	-----	-----	-----
Secchi Depth (in.)	1	23	55	46	11	126	-----	-----	-----
Alkalinity, Total (mg/l)	7	40	149	156	88	176	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	38	4.7	3.6	2.6	41.6	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	40	13	12	9	22	-----	-----	-----
Chloride (mg/l)	1	30	8	9	4	11	175[1,5], 100[1,7], 438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	350	11	8	1	61	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	22	10	8	1	61	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	40	441	432	246	692	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	40	-----	0.05	n.d.	0.47	3.1 [1,5,9], 1.1 [1,7,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	40	0.6	0.5	n.d.	2.5	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	40	-----	0.05	n.d.	0.50	10[2,5]	0	0%
Nitrogen, Total (mg/l)	0.1	40	0.7	0.6	n.d.	2.5	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	40	-----	0.02	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	40	0.05	0.04	n.d.	0.15	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	40	-----	n.d.	n.d.	0.06	-----	-----	-----
Sulfate (mg/l)	1	40	154	157	70	190	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	40	-----	5	n.d.	18	53[1,5], 30[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	23	-----	n.d.	n.d.	0.2	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	23	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	15	65%

n.d. = Not detected.

[A] Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

[B] Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

[C] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[D] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- [1] Criteria for the protection of coldwater permanent fish life propagation waters.
- [2] Criteria for the protection of domestic water supply waters.
- [3] Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- [4] Criteria for the protection of commerce and industry waters.
- [5] Daily maximum criterion (monitoring results directly comparable to criterion).
- [6] Daily minimum criterion (monitoring results directly comparable to criterion).
- [7] 30-day average criterion (monitoring results not directly comparable to criterion).
- [8] The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- [9] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

[E] A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

[F] Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile. (Note: 2009 was the only year where Lake Oahe thermally stratified to the degree that a "true" hypolimnion formed during the summer.)

Plate 163. Summary of monthly (June through September) water quality conditions monitored in Lake Oahe near Beaver Creek (Site OAHLK1256DW) during the 2-year period 2009 through 2010.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	9	1613.9	1613.4	1609.1	1617.1	-----	-----	-----
Water Temperature (°C)	0.1	108	18.7	18.4	10.5	24.6	18.3[1,5]	65	60%
Hypolimnion Water Temperature (°C)[E]	0.1	2	14.5	14.5	14.3	14.7	18.3[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	108	8.6	8.9	5.4	11.4	6[1,6,8], 7[1,6,8]	6, 15	6%, 14%
Dissolved Oxygen (% Sat.)	0.1	108	95.2	97.5	64.7	113.9	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	106	8.6	8.8	5.4	11.4	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	2	9.6	9.6	9.5	9.6	6[1,6,8]	0	0%
Specific Conductance (umhos/cm)	1	108	641	634	302	689	-----	-----	-----
pH (S.U.)	0.1	108	8.2	8.3	7.4	8.9	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	108	6	6	n.d.	31	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	108	372	387	264	495	-----	-----	-----
Secchi Depth (in.)	1	9	48	48	32	67	-----	-----	-----
Alkalinity, Total (mg/l)	7	9	161	162	154	167	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	9	3.7	3.4	2.2	5.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	9	13	11	9	20	-----	-----	-----
Chloride (mg/l)	1	4	10	11	8	11	175[1,5], 100[1,7], 438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	108	19	21	1	34	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	9	16	13	6	26	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	9	451	428	314	632	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	9	-----	0.03	n.d.	0.09	3.1 [1,5,9], 1.1 [1,7,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	9	0.7	0.6	0.3	1.4	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	9	-----	n.d.	n.d.	0.03	10[2,5]	0	0%
Nitrogen, Total (mg/l)	0.1	9	0.7	0.6	0.3	1.4	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	9	-----	0.02	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	9	0.04	0.04	0.02	0.08	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	9	-----	0.02	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	9	159	162	144	177	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	9	7	5	n.d.	17	53[1,5], 30[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	9	-----	n.d.	n.d.	0.2	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	9	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	6	67%

n.d. = Not detected.

[A] Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

[B] Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

[C] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[D] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for the protection of coldwater permanent fish life propagation waters.
- [2] Criteria for the protection of domestic water supply waters.
- [3] Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- [4] Criteria for the protection of commerce and industry waters.
- [5] Daily maximum criterion (monitoring results directly comparable to criterion).
- [6] Daily minimum criterion (monitoring results directly comparable to criterion).
- [7] 30-day average criterion (monitoring results not directly comparable to criterion).
- [8] The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- [9] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

[E] A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

[F] Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

[G] Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

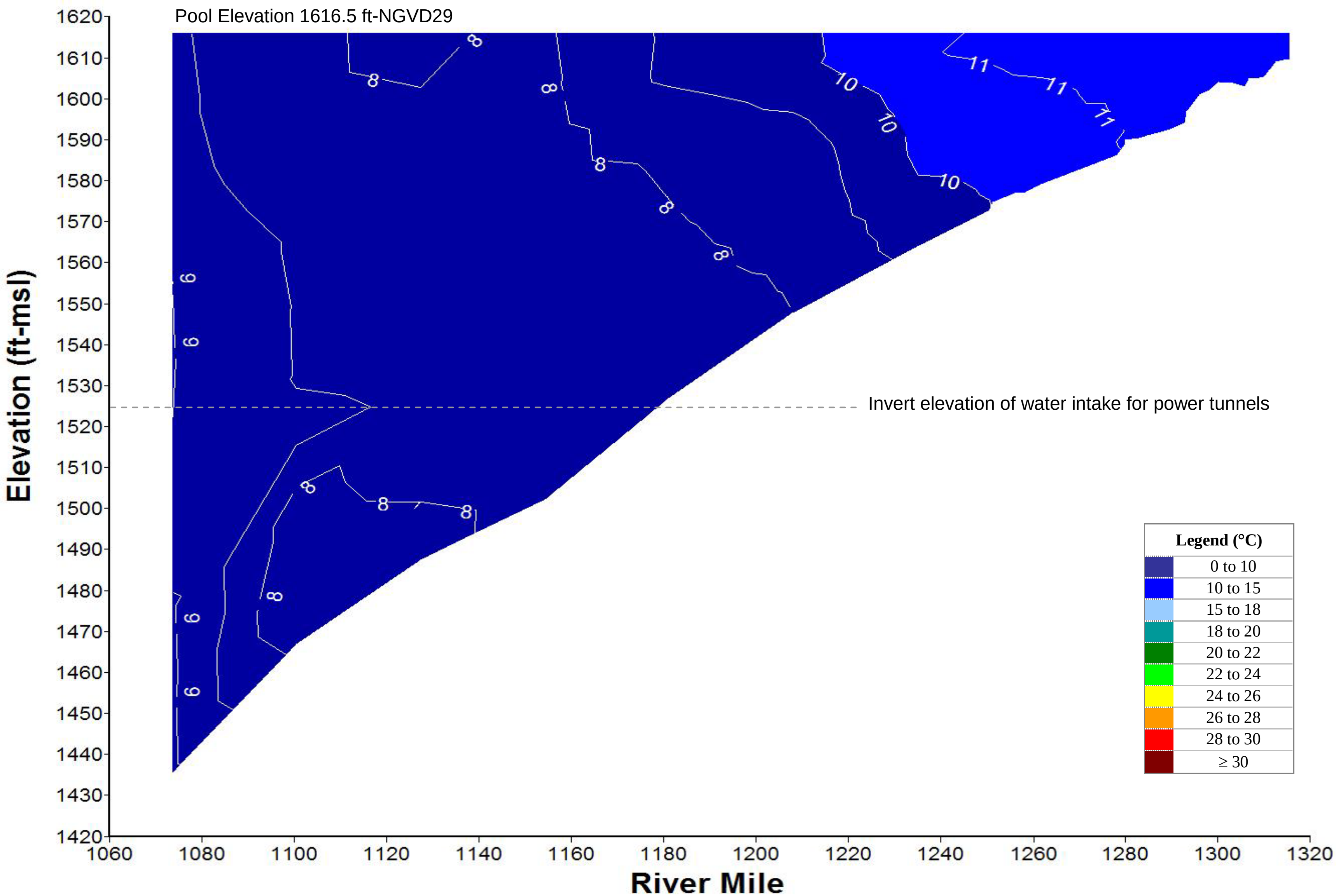

Plate 164. Longitudinal water temperature (°C) contour plot of Lake Oahe based on depth-profile water temperatures measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW and OAHNFMORR1 on May 18, 2010.

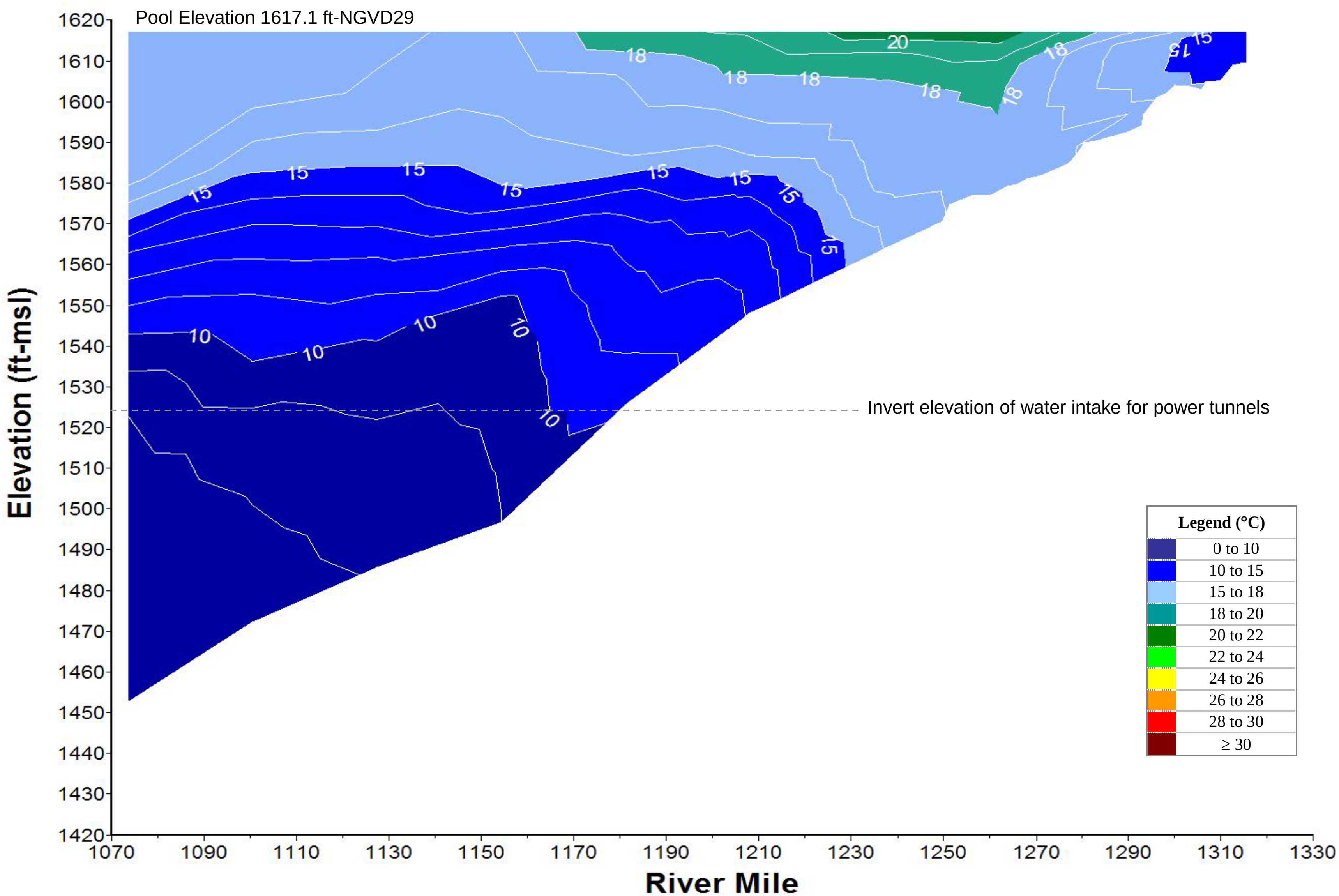

Plate 165. Longitudinal water temperature (°C) contour plot of Lake Oahe based on depth-profile water temperatures measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on June 16, 2010.

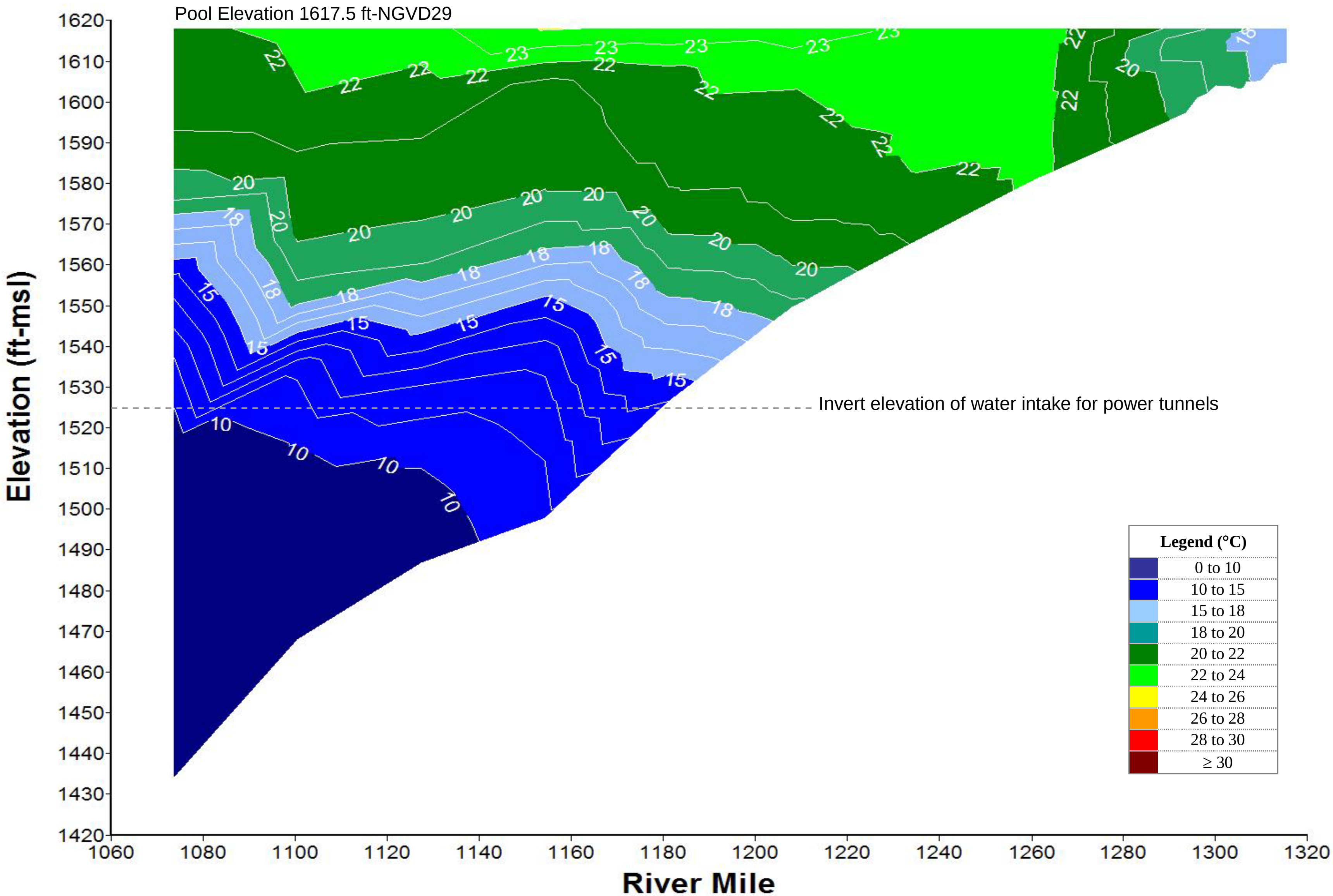

Plate 166. Longitudinal water temperature (°C) contour plot of Lake Oahe based on depth-profile water temperatures measured at sites OAHLK1073A, OAHLK1090DW, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on July 14, 2010.

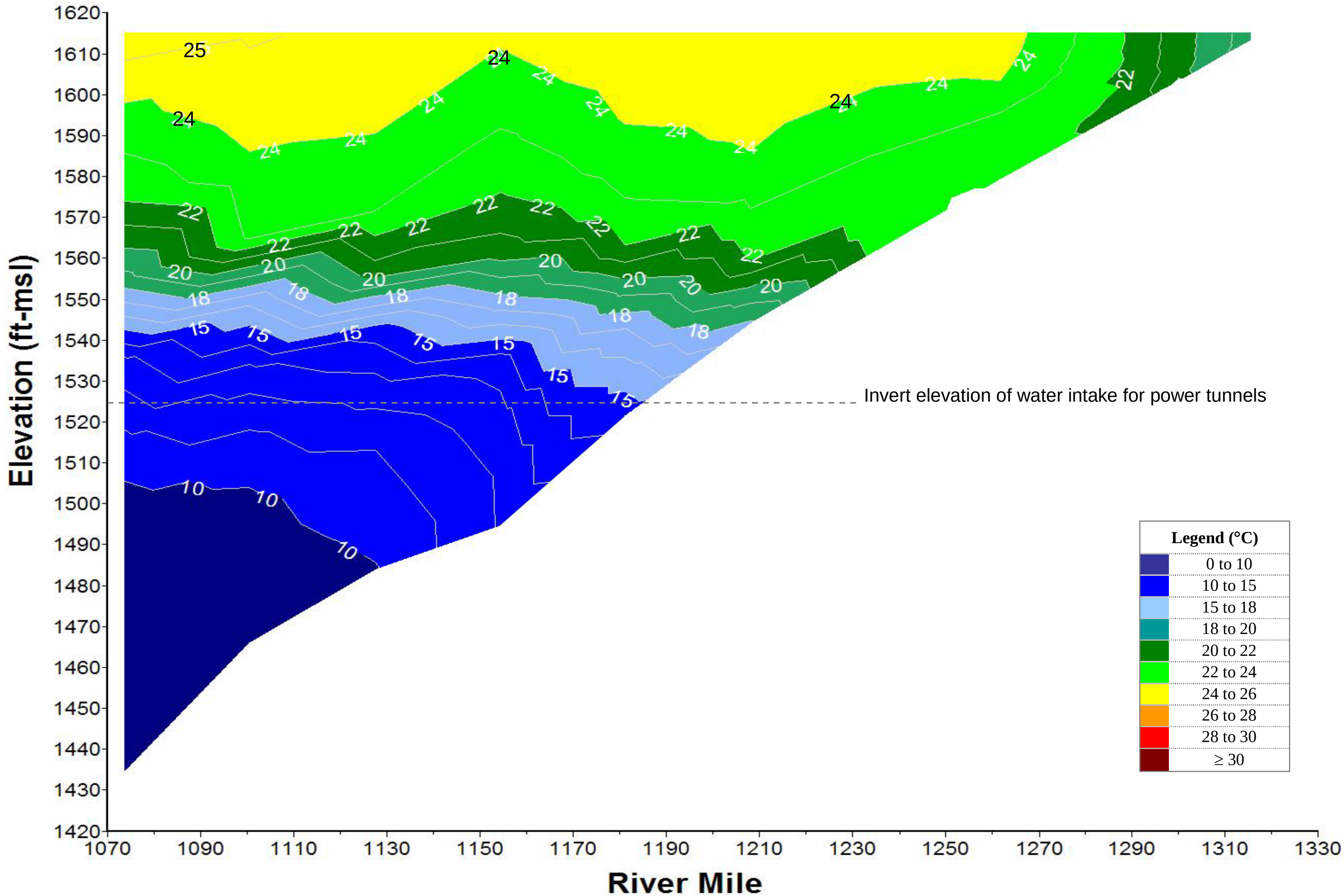

Plate 167. Longitudinal water temperature (°C) contour plot of Lake Oahe based on depth-profile water temperatures measured at sites OAHLK1073A, OAHLK1090DW, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on August 11, 2010.

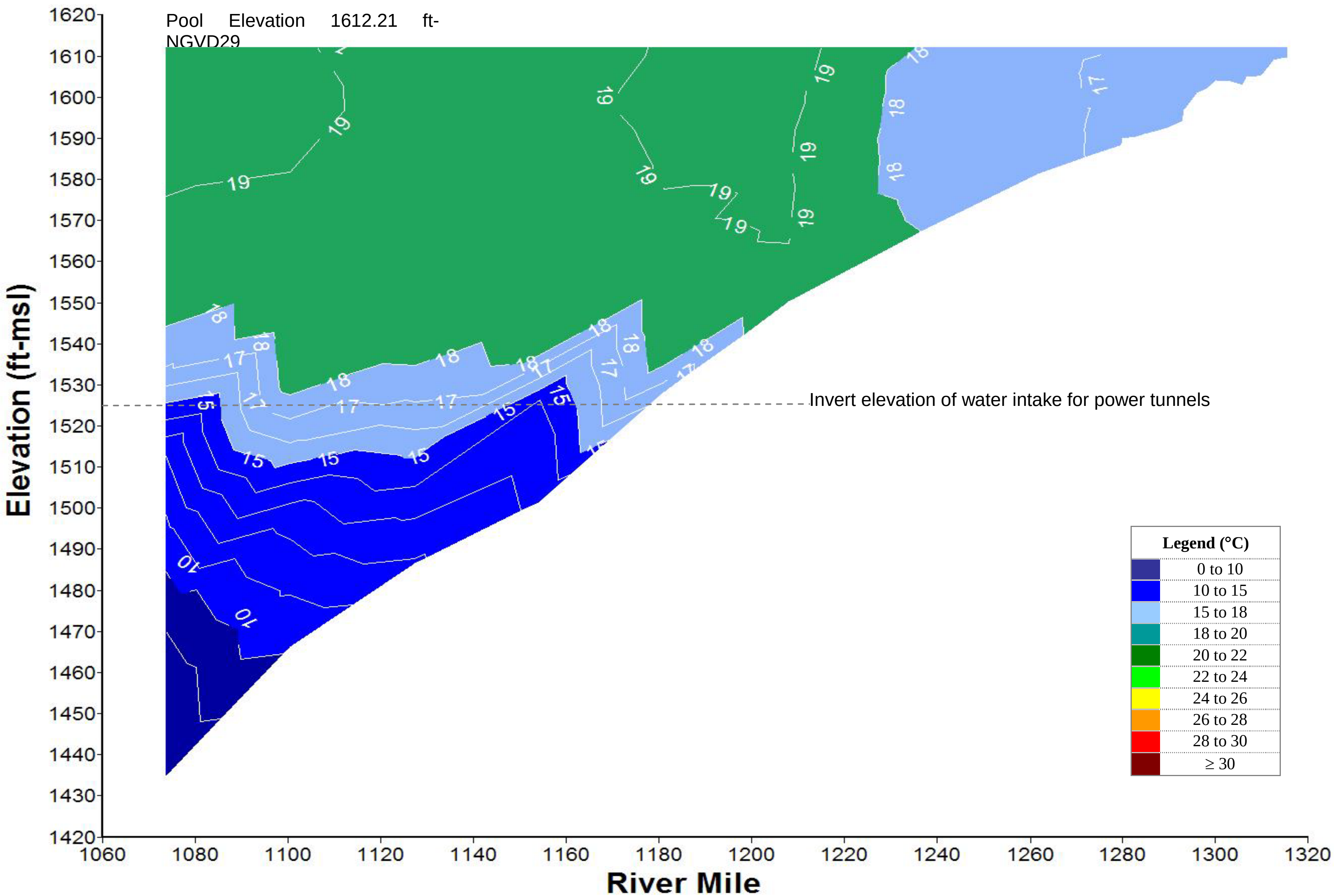

Plate 168. Longitudinal water temperature (°C) contour plot of Lake Oahe based on depth-profile water temperatures measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on September 15, 2010.

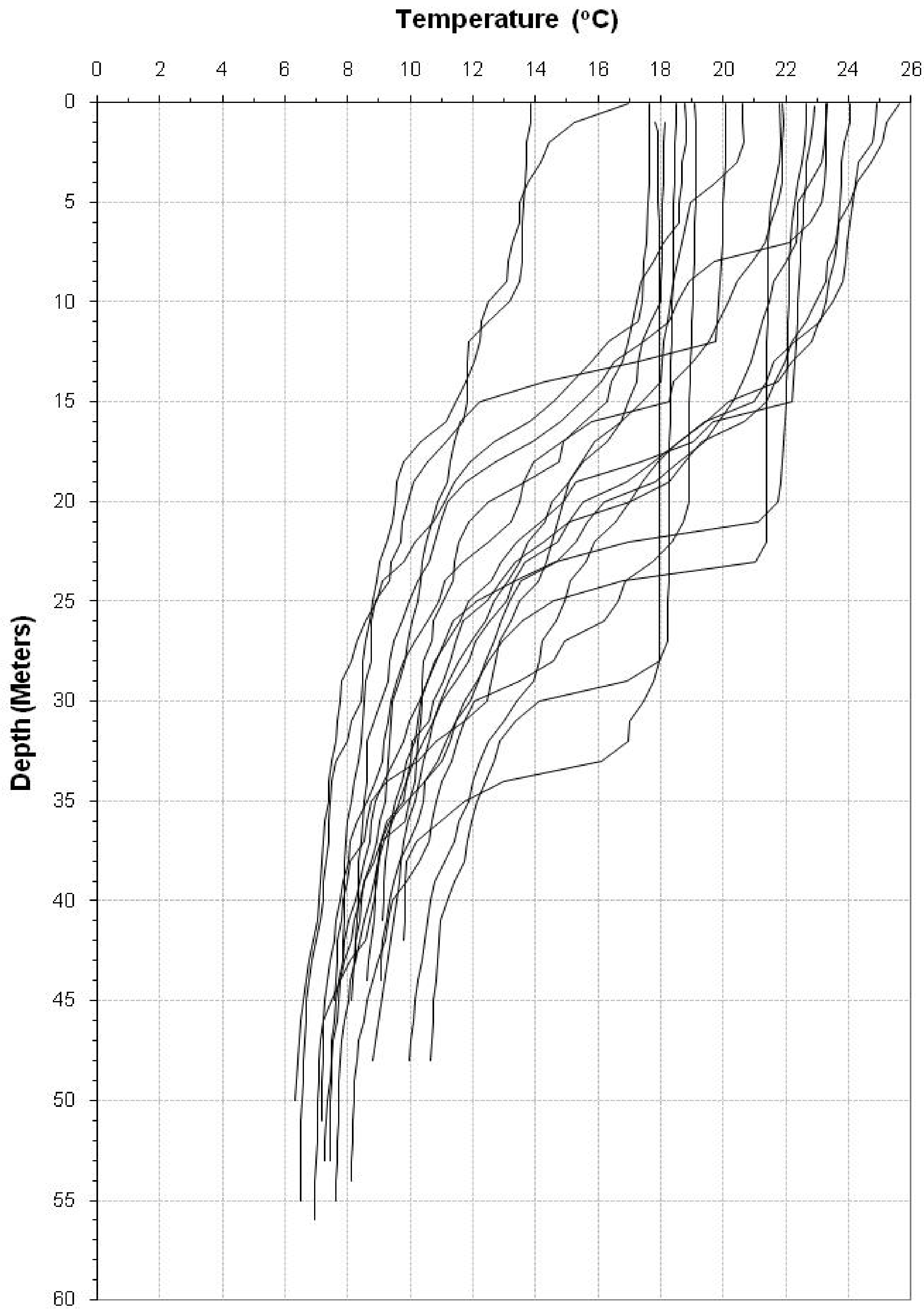

Plate 169. Temperature depth profiles for Lake Oahe generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., OAHLK1073A) during the summer months over the 5-year period of 2006 to 2010.

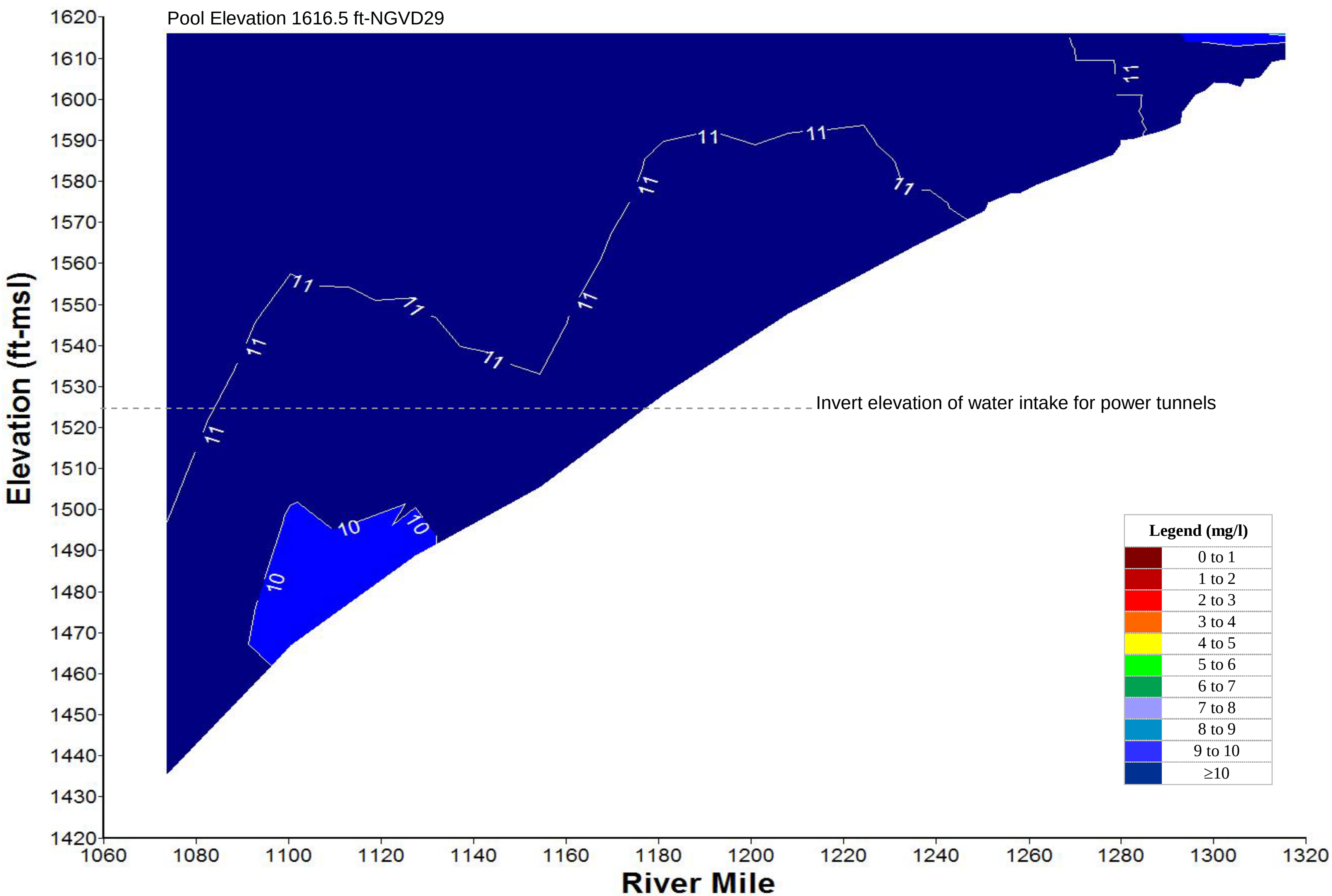

Plate 170. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Oahe based on depth-profile dissolved oxygen concentrations measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on May 18, 2010.

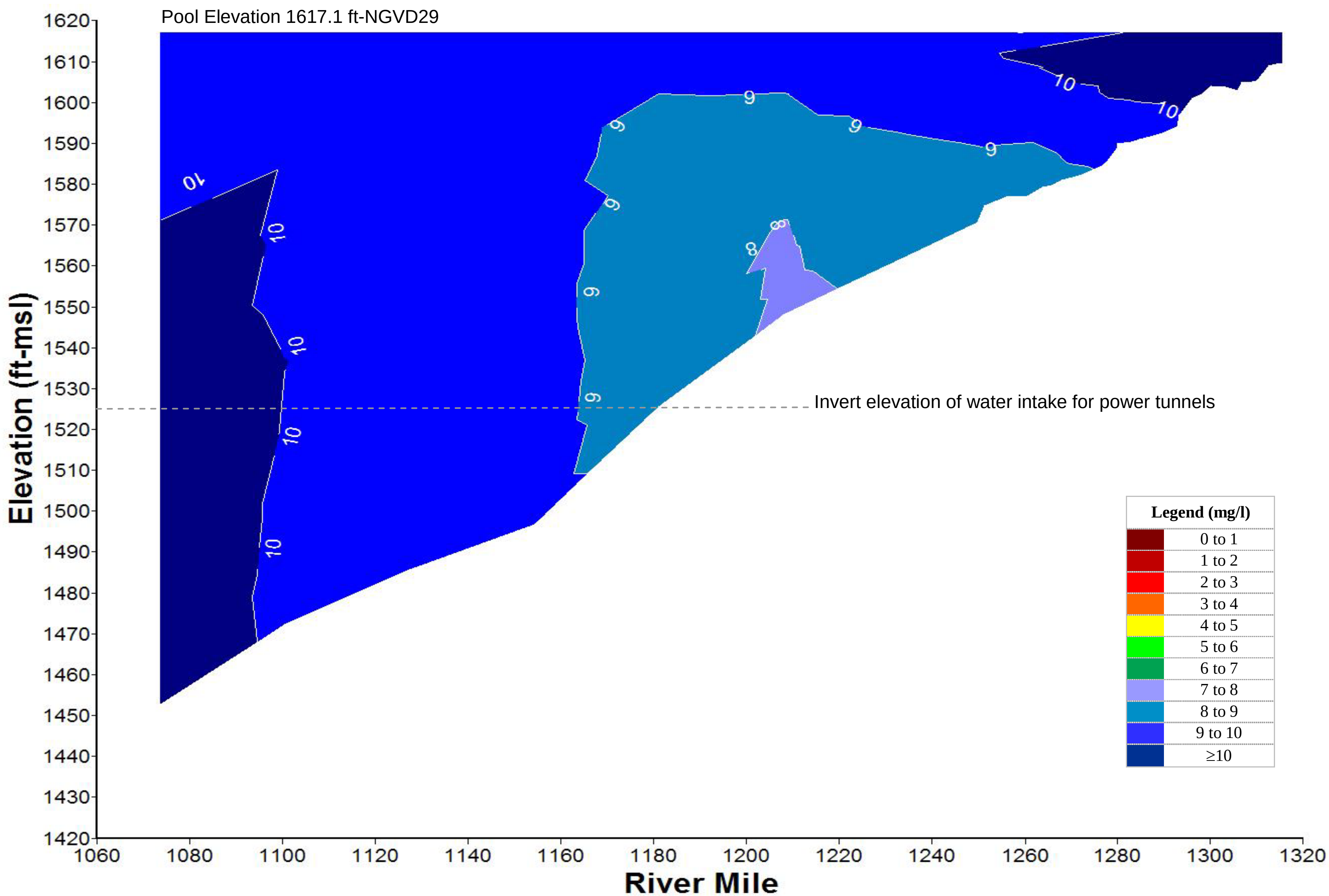

Plate 171. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Oahe based on depth-profile dissolved oxygen concentrations measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on June 16, 2010.

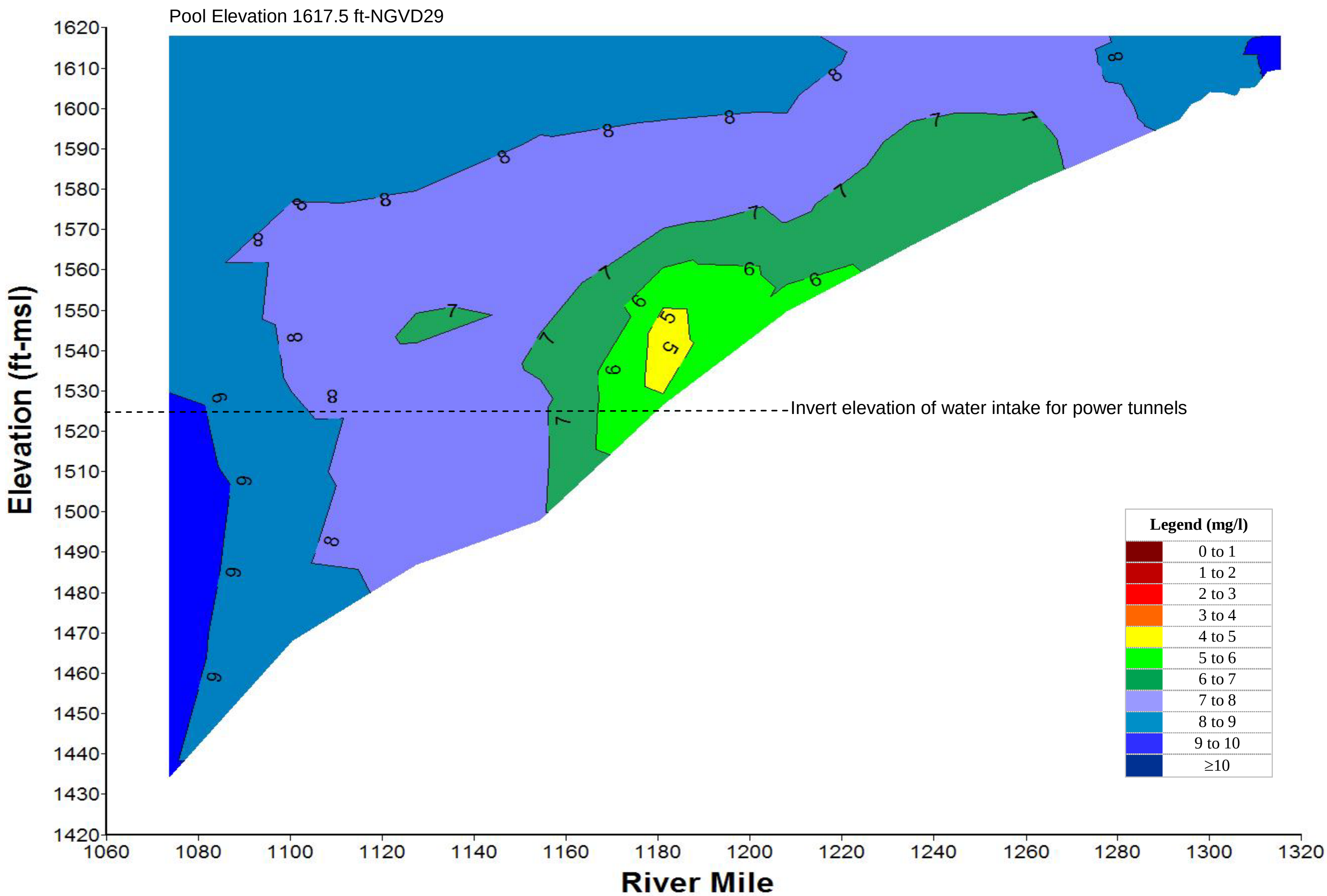

Plate 172. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Oahe based on depth-profile dissolved oxygen concentrations measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on July 14, 2010.

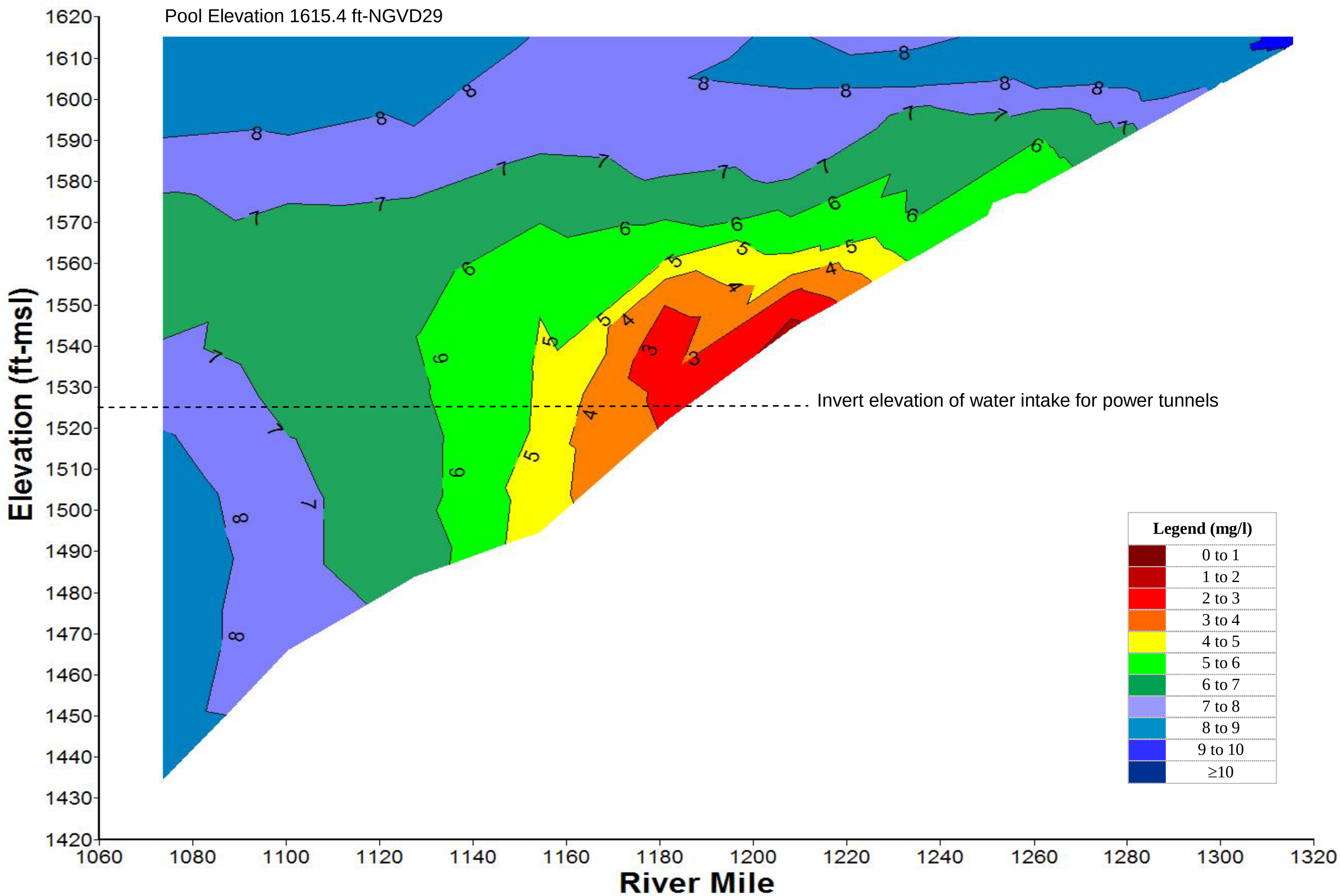

Plate 173. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Oahe based on depth-profile dissolved oxygen concentrations measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on August 11, 2010.

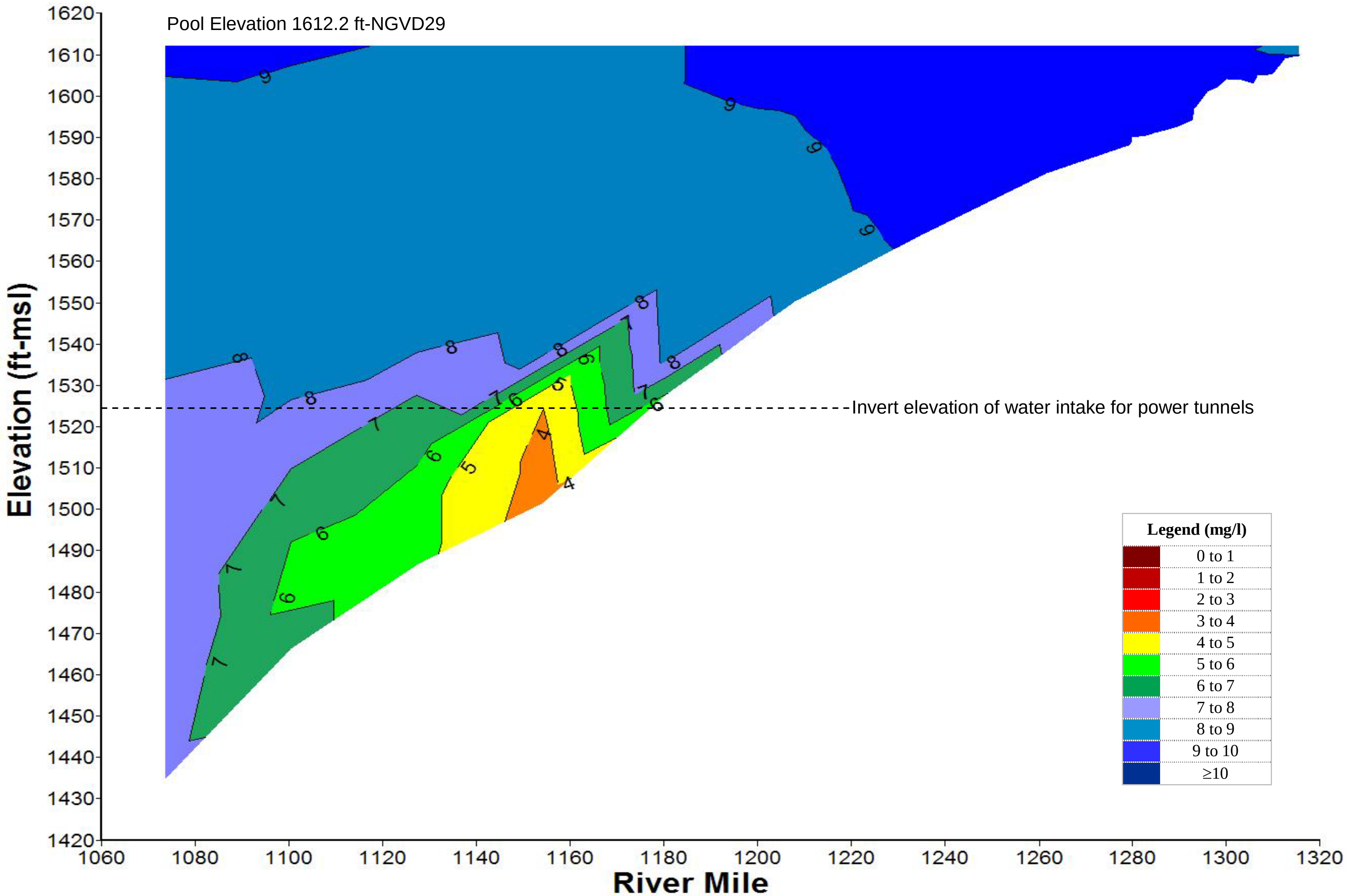

Plate 174. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Oahe based on depth-profile dissolved oxygen concentrations measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on September 15, 2010.

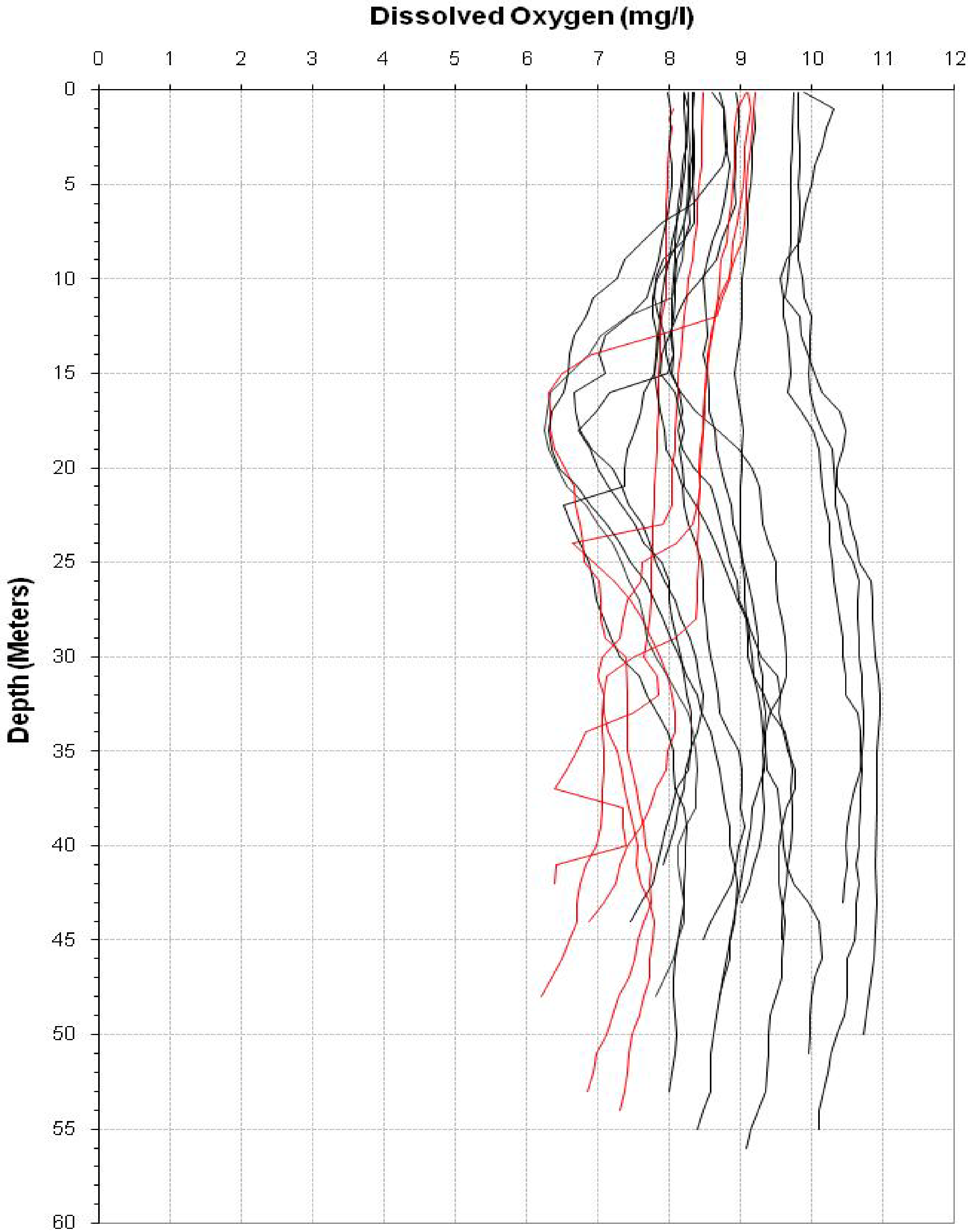

Plate 175. Dissolved oxygen depth profiles for Lake Oahe generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., OAHLK1073A) during the summer months of the 5-year period of 2006 to 2010.
(Note: Red profile plots were measured in the month of September.)

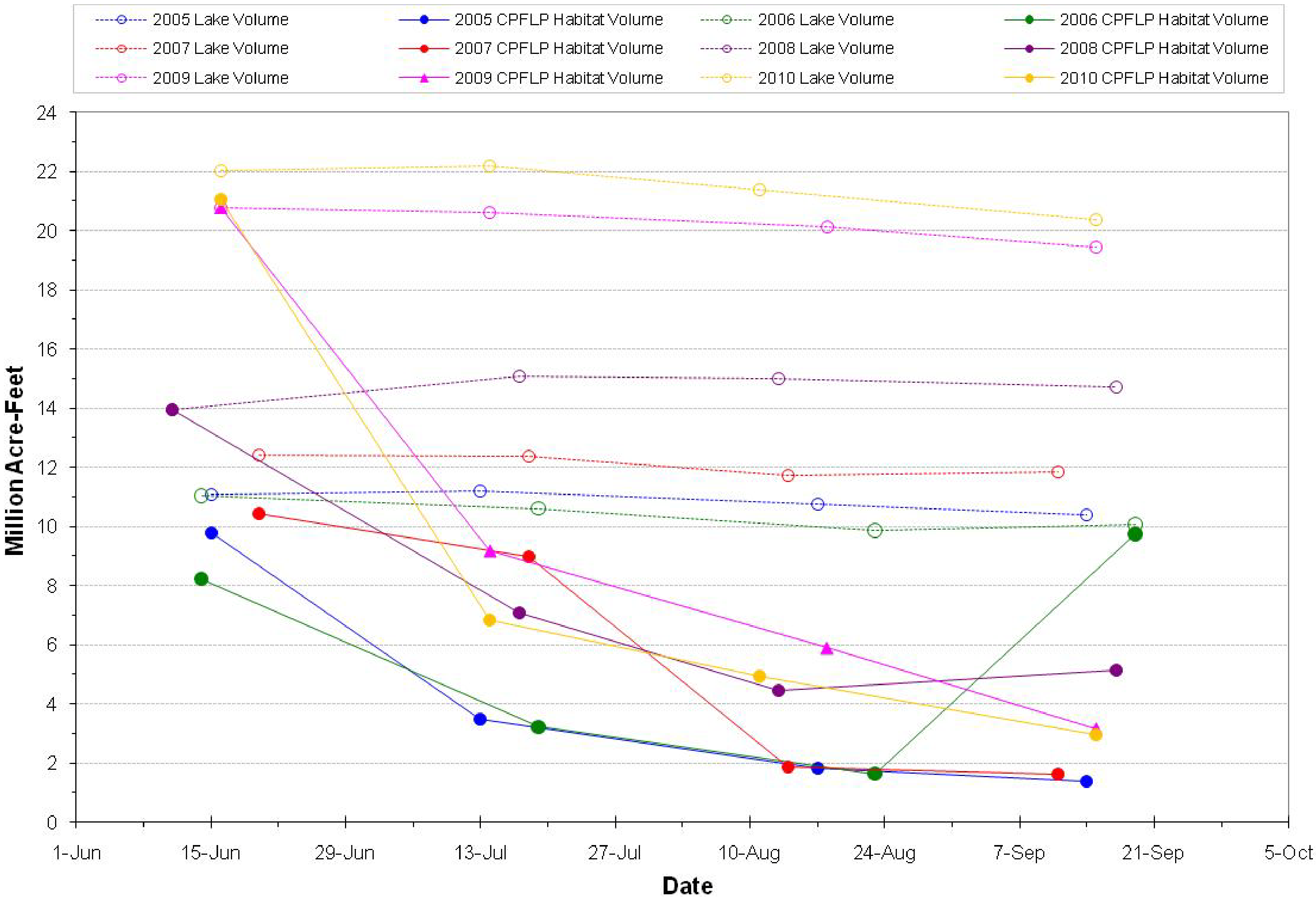

Plate 176. Estimated volume of Coldwater Permanent Fish Life Propagation habitat in Lake Oahe during 2005, 2006, 2007, 2008, 2009, and 2010.

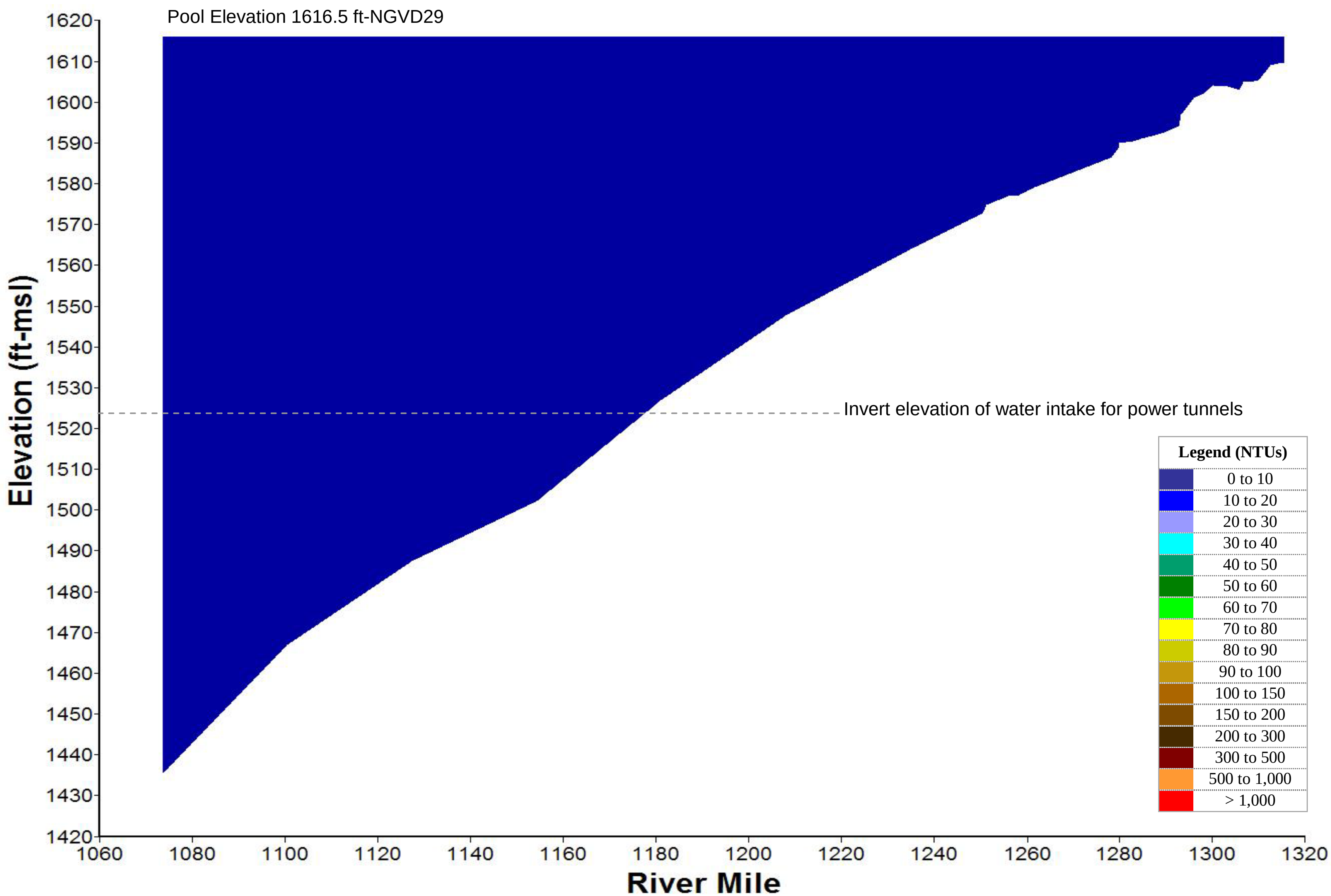

Plate 177. Longitudinal turbidity (NTU) contour plot of Lake Oahe based on depth-profile turbidity levels measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on May 18, 2010.

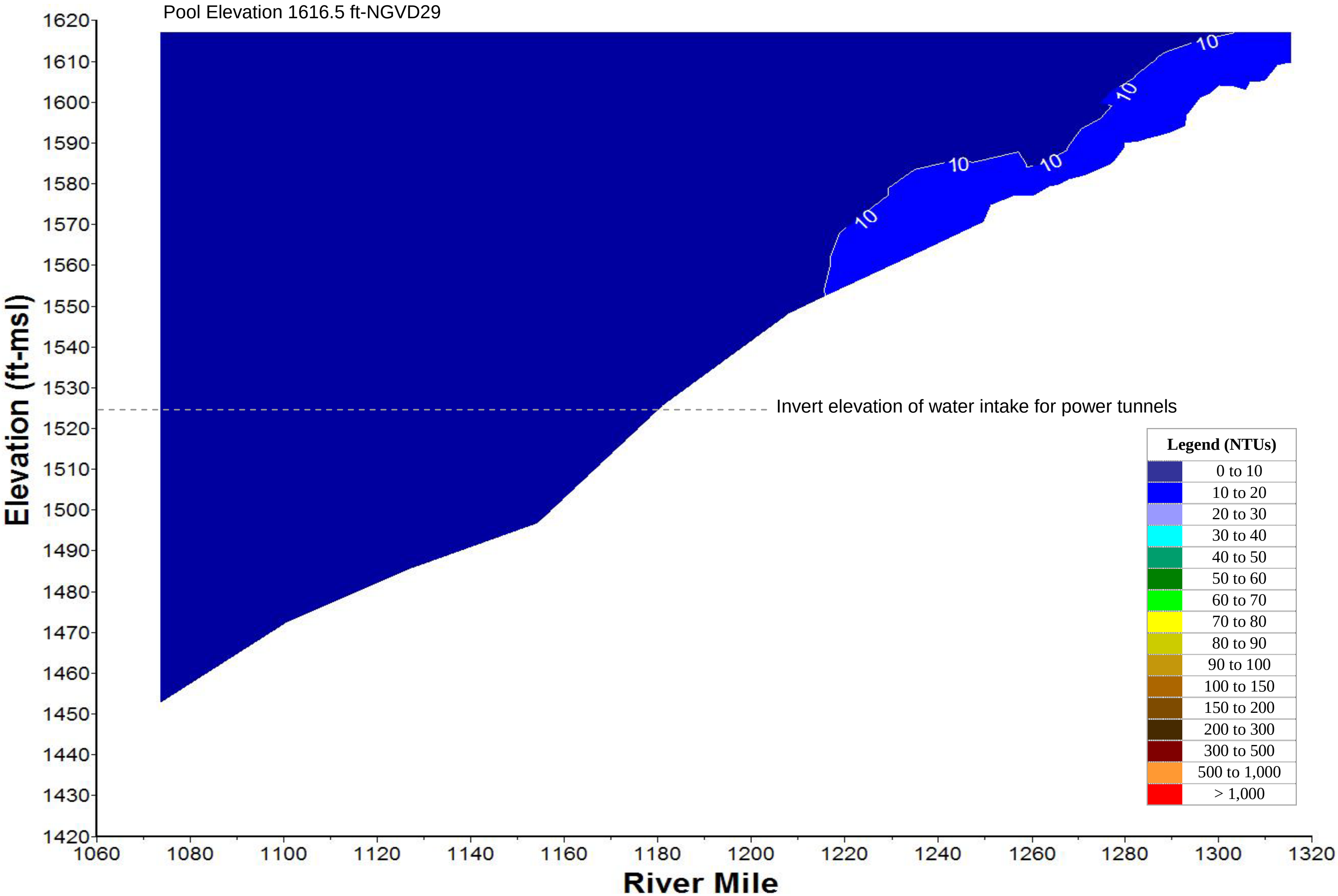

Plate 178. Longitudinal turbidity (NTU) contour plot of Lake Oahe based on depth-profile turbidity levels measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on June 16, 2010.

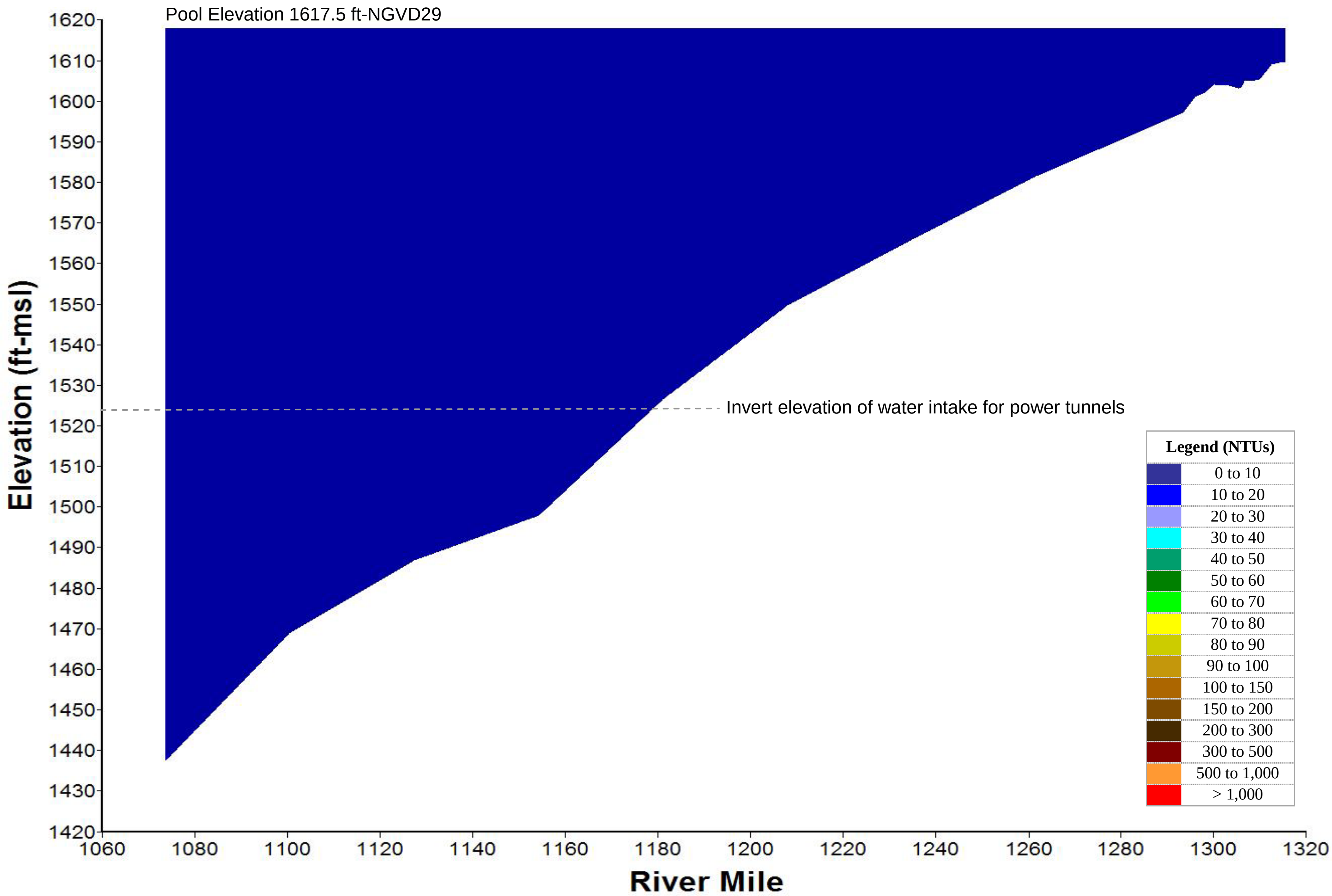

Plate 179. Longitudinal turbidity (NTU) contour plot of Lake Oahe based on depth-profile turbidity levels measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on July 14, 2010.

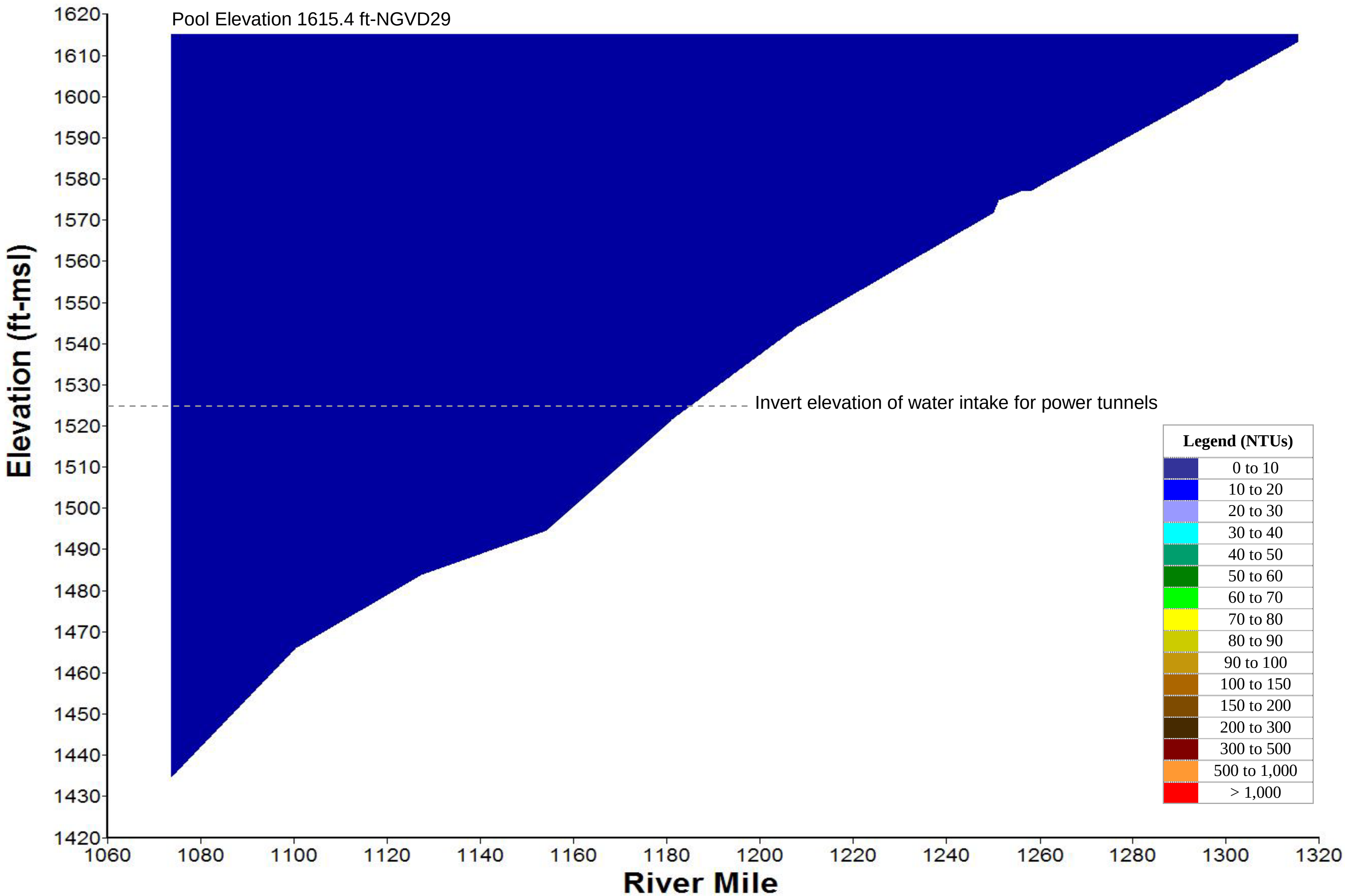

Plate 180. Longitudinal turbidity (NTU) contour plot of Lake Oahe based on depth-profile turbidity levels measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on August 11, 2010.

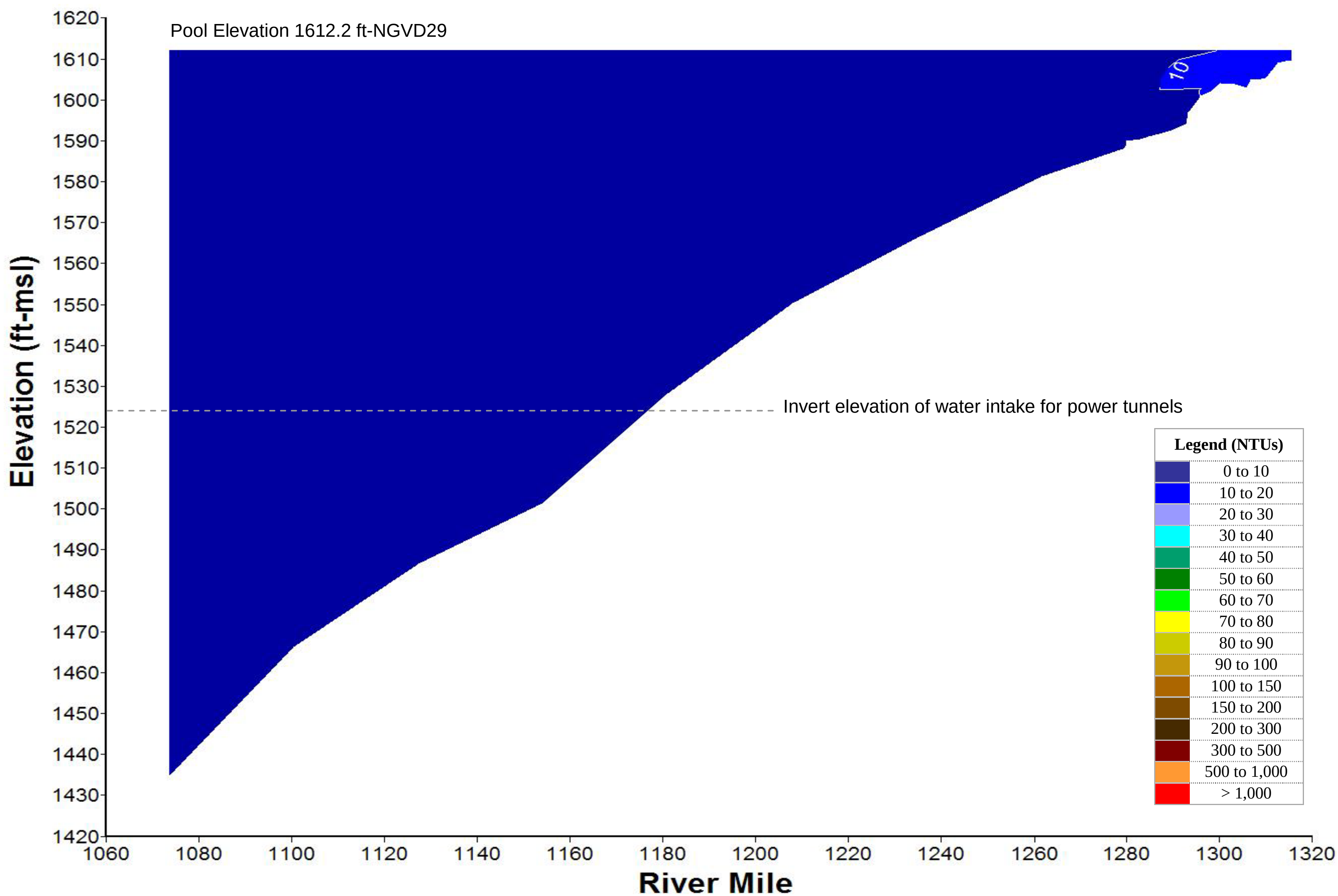

Plate 181. Longitudinal turbidity (NTU) contour plot of Lake Oahe based on depth-profile turbidity levels measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, OAHLK1256DW, and OAHNFMORR1 on September 15, 2010.

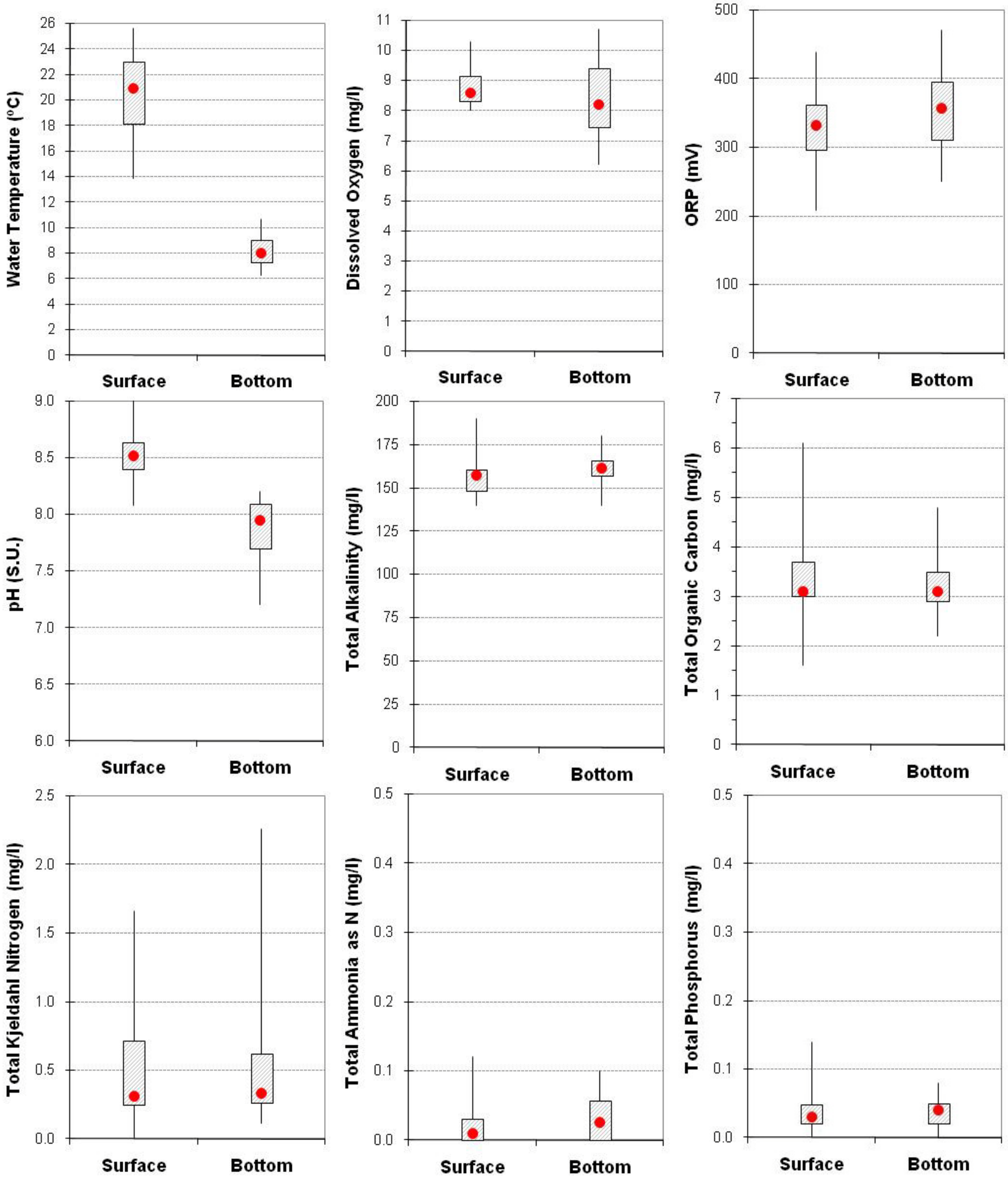

Plate 182. Box plots comparing paired surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus measurements taken in Lake Oahe at site OAHLK1073A during the summer months of the 5-year period 2006 through 2010.
(Box plots display minimum, 25^{th} percentile, 75^{th} percentile, and maximum. Median value is indicated by the red dot.)

Plate 183. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Oahe at site OAHLK1073A during the 5-year period 2006 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
May 2006	0.1867	8	0.97	3	0.01	0	-----	1	0.01	0	-----	1	0.02	0	-----
Jun 2006	0.0954	5	0.76	6	0.18	0	-----	1	0.05	0	-----	0	-----	1	0.01
Jul 2006	0.0216	4	0.17	8	0.46	0	-----	1	0.29	2	0.08	0	-----	0	-----
Aug 2006	0.0527	5	0.42	2	0.06	1	0.08	1	0.11	3	0.11	1	0.22	0	-----
Sep 2006	0.0723	5	0.12	7	0.26	0	-----	1	0.17	2	0.26	1	0.19	0	-----
May 2007	0.1165	7	0.69	5	0.16	2	0.04	1	0.10	0	-----	1	0.01	0	-----
Jun 2007	0.6888	4	0.85	6	0.03	2	0.09	1	0.02	0	-----	2	0.02	0	-----
Jul 2007	0.1127	9	0.71	7	0.04	0	-----	1	0.12	0	-----	2	0.12	0	-----
Aug 2007	0.0454	3	0.04	7	0.08	1	0.11	1	0.35	2	0.07	1	0.35	0	-----
Sep 2007	0.2115	5	0.40	10	0.03	1	0.11	2	0.01	5	0.03	1	0.41	0	-----
May 2008	0.2330	6	0.96	3	<0.01	0	-----	1	0.03	0	-----	0	-----	0	-----
Jun 2008	0.2248	10	0.96	3	0.01	1	<0.01	1	0.02	0	-----	1	0.01	0	-----
Jul 2008	0.0002	6	0.85	5	0.03	1	0.02	0	-----	0	-----	1	0.09	0	-----
Aug 2008	0.0139	2	0.03	3	0.18	1	0.32	1	0.45	2	0.01	0	-----	0	-----
Sep 2008	0.2735	8	0.80	11	0.03	2	0.01	2	0.07	2	0.01	2	0.09	1	<0.01
May 2009	4.6474	7	0.93	3	<0.01	0	-----	2	0.06	1	0.01	0	-----	0	-----
Jun 2009	2.8904	4	0.97	2	<0.01	2	<0.01	2	0.02	0	-----	0	-----	0	-----
Jul 2009	2.0761	14	0.71	9	0.11	0	-----	2	0.01	2	<0.01	2	0.16	2	<0.01
Aug 2009	0.2117	6	0.38	5	0.02	1	0.05	1	0.19	2	<0.01	1	0.35	0	-----
Sep 2009	1.3742	4	0.52	4	0.01	1	0.05	2	0.24	7	0.04	1	0.14	0	-----
May 2010	0.1830	3	0.86	6	0.11	0	-----	2	0.02	0	-----	1	0.01	0	-----
Jul 2010	1.4196	8	0.97	7	0.01	1	<0.01	2	<0.01	1	<0.01	2	0.01	0	-----
Sep 2010	0.3265	8	0.74	9	0.09	0	-----	2	0.11	3	0.04	1	0.02	0	-----
Mean*	**0.6730**	**6.1**	**0.64**	**5.7**	**0.08**	**0.7**	**0.07**	**1.3**	**0.11**	**1.5**	**0.05**	**1.0**	**0.13**	**0.2**	**<0.01**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 184. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Oahe at site OAHLK1110DW during the 5-year period 2006 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
Jun 2006	0.5463	6	0.97	5	0.01	2	<0.01	1	0.02	3	<0.01	1	<0.01	0	-----
Jul 2006	0.0837	6	0.14	3	0.22	0	-----	1	0.19	4	0.20	2	0.24	0	-----
Aug 2006	0.3010	6	0.46	5	0.09	0	-----	1	<0.01	3	0.41	1	0.04	0	-----
Sep 2006	0.1687	6	0.22	15	0.30	1	0.02	1	0.30	3	0.04	2	0.12	2	<0.01
Jun 2007	2.8748	6	0.88	7	0.01	2	0.07	1	0.01	0	-----	1	0.03	0	-----
Jul 2007	0.0618	8	0.14	6	0.13	1	0.38	1	0.13	1	0.01	1	0.22	0	-----
Aug 2007	0.1890	7	0.31	10	0.10	0	-----	1	0.09	1	0.30	1	0.20	1	<0.01
Sep 2007	0.1270	5	0.13	8	0.06	1	0.02	1	0.06	6	0.16	1	0.56	1	0.01
May 2008	0.4190	7	0.97	1	<0.01	1	<0.01	1	0.03	0	-----	1	<0.01	0	-----
Jun 2008	0.4550	11	0.97	8	0.01	2	<0.01	1	0.01	2	<0.01	0	-----	0	-----
Jul 2008	0.0002	3	0.67	12	0.14	1	0.07	1	0.06	0	-----	3	0.06	0	-----
Aug 2008	0.0931	2	0.86	2	<0.01	1	<0.01	1	0.07	3	0.01	2	0.05	0	-----
Sep 2008	0.1982	8	0.46	6	0.06	1	0.01	2	0.32	2	0.04	1	0.11	1	<0.01
May 2009	2.0579	7	0.68	3	0.10	0	-----	2	0.22	1	<0.01	1	<0.01	0	-----
Jun 2009	1.0908	5	0.79	2	0.07	2	<0.01	1	0.14	0	-----	0	-----	0	-----
Jul 2009	1.3357	8	0.57	7	0.36	0	-----	1	0.02	1	<0.01	2	0.06	1	<0.01
Aug 2009	0.4150	4	0.23	6	0.17	1	0.01	2	0.47	2	0.08	1	0.03	1	<0.01
Sep 2009	1.3357	4	0.06	8	0.03	1	<0.01	2	0.17	5	0.05	1	0.65	1	<0.01
May 2010	0.5777	12	0.97	7	0.02	1	<0.01	1	<0.01	2	<0.01	0	-----	0	-----
Jul 2010	1.3884	5	0.95	5	0.02	1	0.01	2	0.01	3	<0.01	1	0.01	0	-----
Sep 2010	0.3873	6	0.91	8	0.03	0	-----	2	0.06	3	<0.01	0	-----	0	-----
Mean*	**0.6970**	**6.3**	**0.59**	**6.4**	**0.09**	**0.9**	**0.04**	**1.3**	**0.11**	**2.1**	**0.08**	**1.1**	**0.14**	**0.4**	**<0.01**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 185. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Oahe at site OAHLK1153DW during the 5-year period 2006 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
Jun 2006	2.8810	8	0.74	13	0.25	1	<0.01	1	<0.01	1	<0.01	1	<0.01	0	-----
Jul 2006	0.4043	3	0.87	6	0.03	1	0.02	1	0.03	2	0.03	1	0.02	0	-----
Aug 2006	0.1165	7	0.22	10	0.28	1	<0.01	1	0.14	5	0.31	2	0.04	1	<0.01
Sep 2006	0.1213	6	0.52	12	0.25	0	-----	1	0.06	4	0.06	1	0.05	2	0.05
Jun 2007	1.7671	10	0.93	10	0.06	1	<0.01	1	0.01	2	<0.01	1	<0.01	0	-----
Jul 2007	0.3019	8	0.53	5	0.06	1	<0.01	1	0.06	2	0.11	1	0.22	1	0.02
Aug 2007	0.1446	6	0.12	9	0.18	1	0.19	1	0.11	4	0.08	1	0.26	2	0.06
Sep 2007	0.2319	5	0.74	14	0.13	0	-----	2	0.04	5	0.04	1	0.02	1	0.03
May 2008	1.1117	15	0.99	1	<0.01	2	<0.01	1	0.01	0	-----	1	<0.01	0	-----
Jun 2008	0.5597	8	0.99	5	<0.01	0	-----	1	0.01	1	<0.01	0	-----	0	-----
Jul 2008	0.0001	2	0.61	7	0.12	1	0.01	1	0.12	2	0.01	1	0.13	0	-----
Aug 2008	0.1193	6	0.87	1	0.01	2	0.02	1	0.04	2	0.05	1	0.01	0	-----
Sep 2008	0.3697	5	0.60	9	0.08	0	-----	2	0.23	2	0.01	3	0.07	1	0.01
May 2009	1.8214	13	0.20	5	0.19	1	<0.01	2	0.61	0	-----	1	<0.01	1	<0.01
Jun 2009	0.6079	13	0.48	5	0.03	1	0.03	2	0.45	0	-----	0	-----	1	<0.01
Jul 2009	1.1619	11	0.89	7	0.08	1	<0.01	2	0.03	1	<0.01	0	-----	0	<0.01
Aug 2009	0.1727	3	0.18	7	0.13	0	-----	1	0.43	3	0.03	1	<0.01	0	-----
Sep 2009	1.2561	7	0.68	12	0.16	0	-----	2	0.09	5	0.07	1	<0.01	0	-----
May 2010	1.7257	7	1.00	1	<0.01	0	-----	0	-----	0	-----	0	-----	0	-----
Jul 2010	0.3561	7	0.84	4	0.01	1	<0.01	2	0.08	2	0.03	2	0.02	1	0.01
Sep 2010	0.4506	6	0.92	7	0.02	0	-----	2	0.03	4	0.01	2	0.01	0	-----
Mean*	**0.7467**	**7.4**	**0.66**	**7.1**	**0.10**	**0.7**	**0.02**	**1.3**	**0.14**	**2.2**	**0.05**	**1.0**	**0.05**	**0.5**	**0.02**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 186. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Oahe at site OAHLK1196DW during the 5-year period 2006 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
Jun 2006	0.6096	6	0.98	7	0.01	0	-----	1	<0.01	2	<0.01	1	<0.01	0	-----
Jul 2006	0.9683	10	0.98	4	<0.01	1	<0.01	1	<0.01	4	<0.01	1	0.01	1	<0.01
Aug 2006	2.0607	13	0.95	6	0.02	0	-----	1	0.02	3	<0.01	2	0.01	1	<0.01
Sep 2006	0.8527	13	0.95	8	0.03	0	-----	1	0.01	2	<0.01	1	<0.01	1	<0.01
Jun 2007	1.8199	10	0.91	10	0.07	1	<0.01	1	0.01	2	0.01	0	-----	0	-----
Jul 2007	0.8002	10	0.65	8	0.02	0	-----	1	0.04	1	0.15	2	0.15	0	-----
Aug 2007	1.4976	8	0.91	8	0.02	1	<0.01	0	-----	1	0.02	1	0.03	3	0.01
Sep 2007	0.8872	9	0.94	8	0.03	0	-----	1	0.01	3	<0.01	1	0.02	2	<0.01
May 2008	0.5369	11	0.98	2	<0.01	2	0.01	1	0.01	1	<0.01	0	-----	1	<0.01
Jun 2008	0.5917	11	0.95	8	<0.01	1	<0.01	1	0.04	0	-----	0	-----	1	<0.01
Jul 2008	0.0002	3	0.40	6	0.09	0	-----	1	0.42	3	0.01	2	0.08	0	-----
Aug 2008	0.2137	9	0.72	8	0.01	3	0.01	1	0.20	6	0.06	2	<0.01	0	-----
Sep 2008	0.1729	7	0.46	7	0.10	1	<0.01	2	0.34	4	0.08	2	0.03	1	<0.01
May 2009	0.1290	11	0.43	6	0.09	1	<0.01	2	0.43	0	-----	1	0.02	1	0.02
Jun 2009	0.5732	7	0.79	6	0.05	1	<0.01	2	0.16	0	-----	0	-----	0	-----
Jul 2009	0.2524	5	0.85	5	0.09	1	0.03	1	0.02	2	0.01	0	-----	0	-----
Aug 2009	5.1533	7	0.49	8	0.01	2	<0.01	2	0.02	4	<0.01	1	0.47	0	-----
Sep 2009	1.0013	11	0.57	11	0.13	1	<0.01	2	0.12	6	0.17	0	-----	0	-----
May 2010	0.8938	7	0.83	2	0.04	1	<0.01	1	0.13	0	-----	1	<0.01	0	-----
Jul 2010	0.4940	5	0.87	1	0.01	0	-----	2	0.10	5	0.02	1	<0.01	0	-----
Sep 2010	0.2798	6	0.78	8	0.02	1	<0.01	2	0.02	5	0.15	1	0.02	0	-----
Mean*	**0.9423**	**8.5**	**0.78**	**6.5**	**0.04**	**0.9**	**<0.01**	**1.3**	**0.11**	**2.6**	**0.04**	**1.0**	**0.06**	**0.6**	**<0.01**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 187. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Oahe at site OAHLK1256DW during the 2-year period 2009 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
Jun 2009	0.1435	7	0.10	10	0.04	1	0.08	1	0.48	5	0.30	0	-----	0	-----
Jul 2009	0.4458	11	0.82	1	0.06	1	0.06	1	0.03	3	0.03	1	<0.01	1	<0.01
Aug 2009	2.7633	13	0.86	10	0.02	2	0.02	2	0.08	3	<0.01	1	<0.01	0	-----
Sep 2009	2.8369	18	0.84	5	<0.01	2	0.03	2	0.11	4	0.01	2	0.01	2	<0.01
May 2010	1.03247	11	0.98	1	<0.01	2	0.01	1	<0.01	0	-----	0	-----	2	<0.01
Jul 2010	0.5387	6	0.83	7	0.06	0	-----	1	0.02	6	0.09	2	<0.01	0	-----
Sep 2010	0.5392	14	0.89	11	0.05	2	<0.01	2	0.05	1	<0.01	1	<0.01	3	<0.01
Mean*	**1.1857**	**11.4**	**0.76**	**6.4**	**0.03**	**1.4**	**0.03**	**1.4**	**0.11**	**3.1**	**0.07**	**1.0**	**<0.01**	**1.1**	**<0.01**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 188. Estimated biomass, number of species, and percent composition (based on biomass) by taxonomic grouping for zooplankton tow samples collected in Lake Oahe at Sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, and OAHLK1256DW during 2010.

Date	Estimated Biomass (µg/L dry wt.)	Cladocerans		Copepods		Rotifers	
		No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.
Site OAHLK1073A – Near Dam							
May 2010	8.392	0	-----	3	0.80	6	0.20
July 2010	26.591	3	0.46	4	0.52	7	0.01
Sept 2010	3.895	2	0.33	5	0.87	5	0.13
Mean	**12.959**	**1.7**	**0.40**	**4.0**	**0.73**	**6.0**	**0.11**
Site OAHLK1110DW – Cheyenne River							
May 2010	10.064	0	-----	2	0.67	9	0.33
July 2010	39.207	4	0.69	4	0.30	6	0.01
Sept 2010	5.286	2	0.16	4	0.75	4	0.08
Mean	**22.247**	**3.0**	**0.43**	**4.0**	**0.53**	**5.0**	**0.05**
Site OAHLK1153DW – Whitlock Bay							
May 2010	26.443	0	-----	3	0.80	8	0.20
July 2010	18.549	2	0.50	2	0.46	6	0.04
Sept 2010	22.765	3	0.60	6	0.37	6	0.03
Mean	**22.586**	**1.7**	**0.55**	**3.7**	**0.54**	**6.7**	**0.09**
Site OAHLK1196DW – Mobridge							
May 2010	23.440	0	-----	2	0.76	9	0.24
July 2010	26.354	3	0.61	4	0.38	6	0.01
Sept 2010	140.813	3	0.95	6	0.04	4	0.01
Mean	**63.536**	**2.0**	**0.78**	**4.0**	**0.39**	**6.3**	**0.09**
Site OAHLK1256DW – Beaver Creek							
May 2010	15.220	2	0.16	4	0.68	11	0.17
July 2010	52.759	3	0.89	4	0.10	6	0.01
Sept 2010*	16.359	3	0.60	4	0.32	12	0.07
Mean	**28.113**	**2.7**	**0.55**	**4.0**	**0.37**	**9.7**	**0.08**

* Ostracods (“seed shrimp”) were collected in the zooplankton sample on this date and comprised < 1% of the sampled zooplankton.

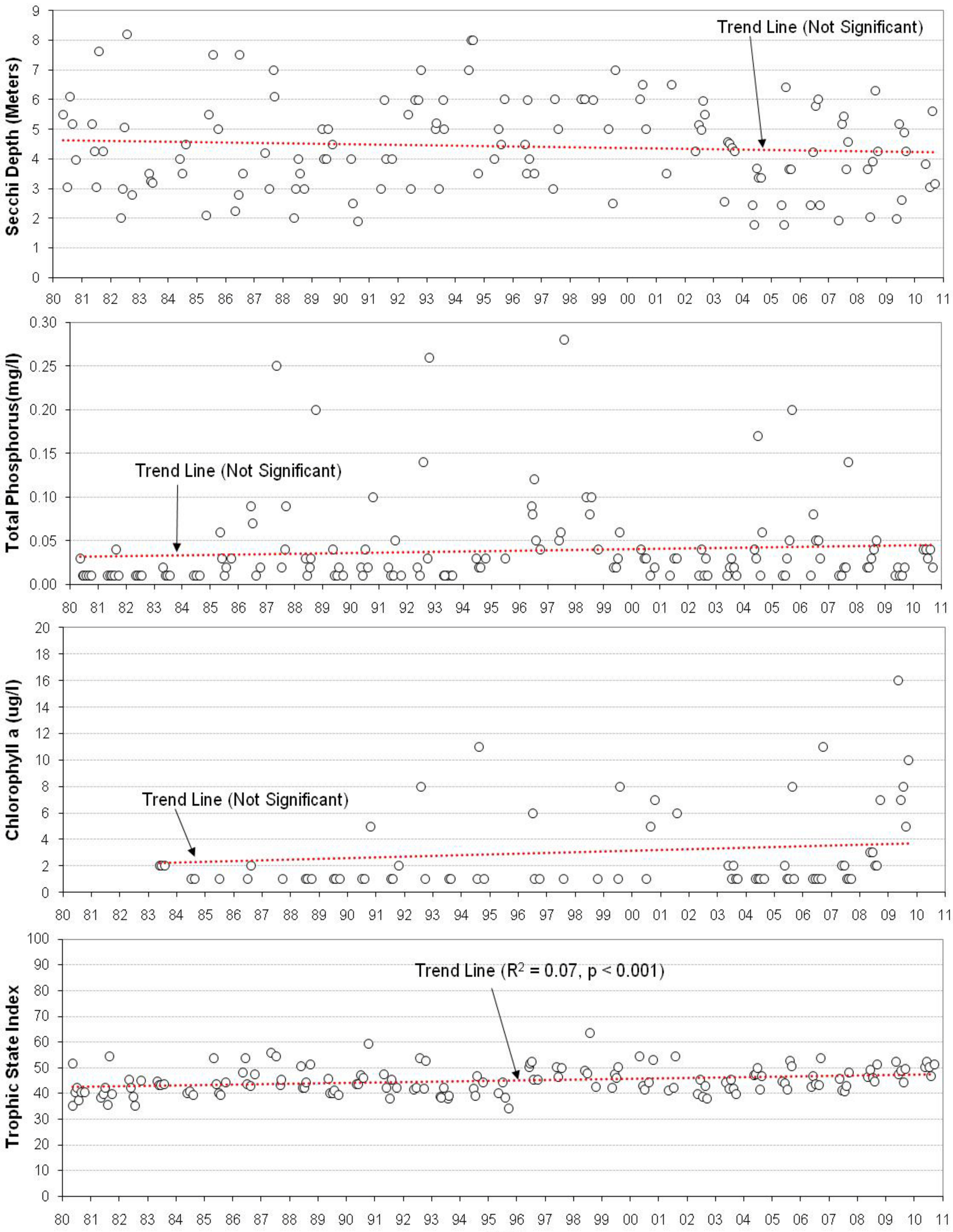

Plate 189. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Lake Oahe at the near-dam, ambient site (i.e., site OAHLK1073A) over the 31-year period of 1980 through 2010.

Plate 190. Summary of monthly (April through September) near-surface water quality conditions monitored in the Missouri River at Bismarck, North Dakota at monitoring site OAHNFMORR1 during the 5-year period 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[(A)]	No. of Obs.	Mean[(B)]	Median	Min.	Max.	State WQS Criteria[(C)]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	28	16,162	15,250	10,564	28,900	-----	-----	-----
Water Temperature (°C)	0.1	26	17.3	17.9	7.4	25.5	29.4[(1,2)]	0	0%
Dissolved Oxygen (mg/l)	0.1	26	9.5	9.3	8.7	11.6	5[(1,3)]	0	0%
Dissolved Oxygen (% Sat.)	0.1	26	102.6	102.3	94.7	109.9	-----	-----	-----
pH (S.U.)	0.1	26	8.2	8.3	7.6	8.6	7.0[(1,3)], 9.0[(1,2)]	0	0%
Specific Conductance (umhos/cm)	1	26	622	621	561	727	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	26	370	355	273	531	-----	-----	-----
Turbidity (NTU)	1	26	23	5	n.d.	134	-----	-----	-----
Secchi Depth (in)	1	5	30	34	6	48	-----	-----	-----
Alkalinity, Total (mg/l)	7	28	155	154	140	185	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	27	3.0	3.0	n.d.	5.3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	28	11	11	2	24	-----	-----	-----
Chloride, Dissolved (mg/l)	1	22	10	10	8	11	100[(1,2)]	0	0%
Chlorophyll *a* (ug/l)	1	6	6	6	1	10	-----	-----	-----
Color, True (APHA)	1	6	9	6	4	21	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	28	432	420	284	620	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	28	-----	n.d.	n.d.	0.11	4.7 [(1,2,4)], 1.1 [(1,4,5)]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	28	0.4	0.3	n.d.	1.3	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	28	-----	0.07	n.d.	0.14	1.0[(1,2)]	0	0%
Nitrogen, Total (mg/l)	0.1	28	0.4	0.4	n.d.	1.3	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	28	-----	n.d.	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	28	0.05	0.04	n.d.	0.21	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	28	-----	n.d.	n.d.	0.06	-----	-----	-----
Sulfate (mg/l)	1	28	157	152	141	190	250[(1,2)]	0	0%
Suspended Sediment, Total (mg/l)	4	6	41	41	6	99	-----	-----	-----
Suspended Solids, Total (mg/l)	4	28	22	19	n.d.	94	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Turbidity, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for Class 1 streams.
- (2) Daily maximum criterion (monitoring results directly comparable to criterion).
- (3) Daily minimum criterion (monitoring results directly comparable to criterion).
- (4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (5) 30-day average criterion (monitoring results not directly comparable to criterion).

Plate 191. Summary of annual metals and pesticide levels monitored in the Missouri River at Bismarck, North Dakota at monitoring site OAHNFMORR1 during the 5-year period 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Aluminum, Total (ug/l)	25	4	286	287	200	370	750[6]	0	0%
Antimony, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Antimony, Total (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	5.6[8]	0	0%
Arsenic, Dissolved (ug/l)	1	4	-----	1	n.d.	1	-----	-----	-----
Arsenic, Total (ug/l)	1	4	-----	1	n.d.	2	340[1], 150[2], 10[3]	0	0%
Barium, Dissolved (ug/l)	5	4	56	54	51	64	-----	-----	-----
Barium, Total (ug/l)	5	4	61	60	55	70	1,000[8]	0	0%
Beryllium, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Beryllium, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	4[8]	0	0%
Cadmium, Dissolved (ug/l)	0.2	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Cadmium, Total (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	4.3[6], 0.45[7], 5[8]	0	0%
Calcium, Dissolved (mg/l)	0.4	5	50	49	43	56	-----	-----	-----
Chromium, Dissolved (ug/l)	10	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Chromium, Total (ug/l)	10	4	-----	n.d.	n.d.	n.d.	3,167[6], 158[7], 100[8]	0	0%
Copper, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Copper, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	27[6], 17[7], 1,000[8]	0	0%
Hardness, Total (mg/l)	0.4	5	204	199	179	225	-----	-----	-----
Iron, Dissolved (ug/l)	40	9[A]	-----	10	n.d.	40	-----	-----	-----
Iron, Total (ug/l)	40	13[A]	476	360	190	1,614	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Lead, Total (ug/l)	0.5	5	-----	n.d.	n.d.	0.6	196[6], 7.6[7], 15[8]	0	0%
Magnesium, Dissolved (mg/l)	0.4	5	19	18	17	21	-----	-----	-----
Manganese, Dissolved (ug/l)	2	13[A]	-----	3	n.d.	10	-----	-----	-----
Manganese, Total (ug/l)	2	13[A]	18	16	9	41	-----	-----	-----
Mercury, Dissolved (ug/l)	0.02	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Mercury, Total (ug/l)	0.02	5	-----	n.d.	n.d.	n.d.	1.7[6], 0.012[7], 0.05[8]	0, b.d., 0	0%
Nickel, Dissolved (ug/l)	10	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Nickel, Total (ug/l)	10	4	-----	n.d.	n.d.	n.d.	840[6], 93[7], 100[8]	0	0%
Selenium, Total (ug/l)	1	3	-----	n.d.	n.d.	n.d.	20[6], 5[7], 50[8]	0	0%
Silver, Dissolved (ug/l)	1	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Silver, Total (ug/l)	1	4	-----	n.d.	n.d.	n.d.	14[6]	0	0%
Sodium, Dissolved (mg/l)	0.4	1	58	58	58	58	-----	-----	-----
Thallium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Total (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	0.24[7]	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	5	-----	n.d.	n.d.	30	-----	-----	-----
Zinc, Total (ug/l)	10	4	-----	n.d.	n.d.	50	215[6,7], 7,400[8]	0	0%
Pesticide Scan (ug/l)[D]	0.05[E]	4	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

[A] Results for iron (dissolved and total) and manganese (dissolved and total) include some monthly samples.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for Class 1 streams.
- [2] Daily maximum criterion (monitoring results directly comparable to criterion).
- [3] Daily minimum criterion (monitoring results directly comparable to criterion).
- [4] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- [5] 30-day average criterion (monitoring results not directly comparable to criterion).
- [6] Acute criterion for aquatic life.
- [7] Chronic criterion for aquatic life.
- [8] Human health criterion for surface waters.

Note: Some of North Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

[E] Detection limits vary by pesticide – 0.05 ug/l is a median detection limit for the pesticides in the pesticide scan.

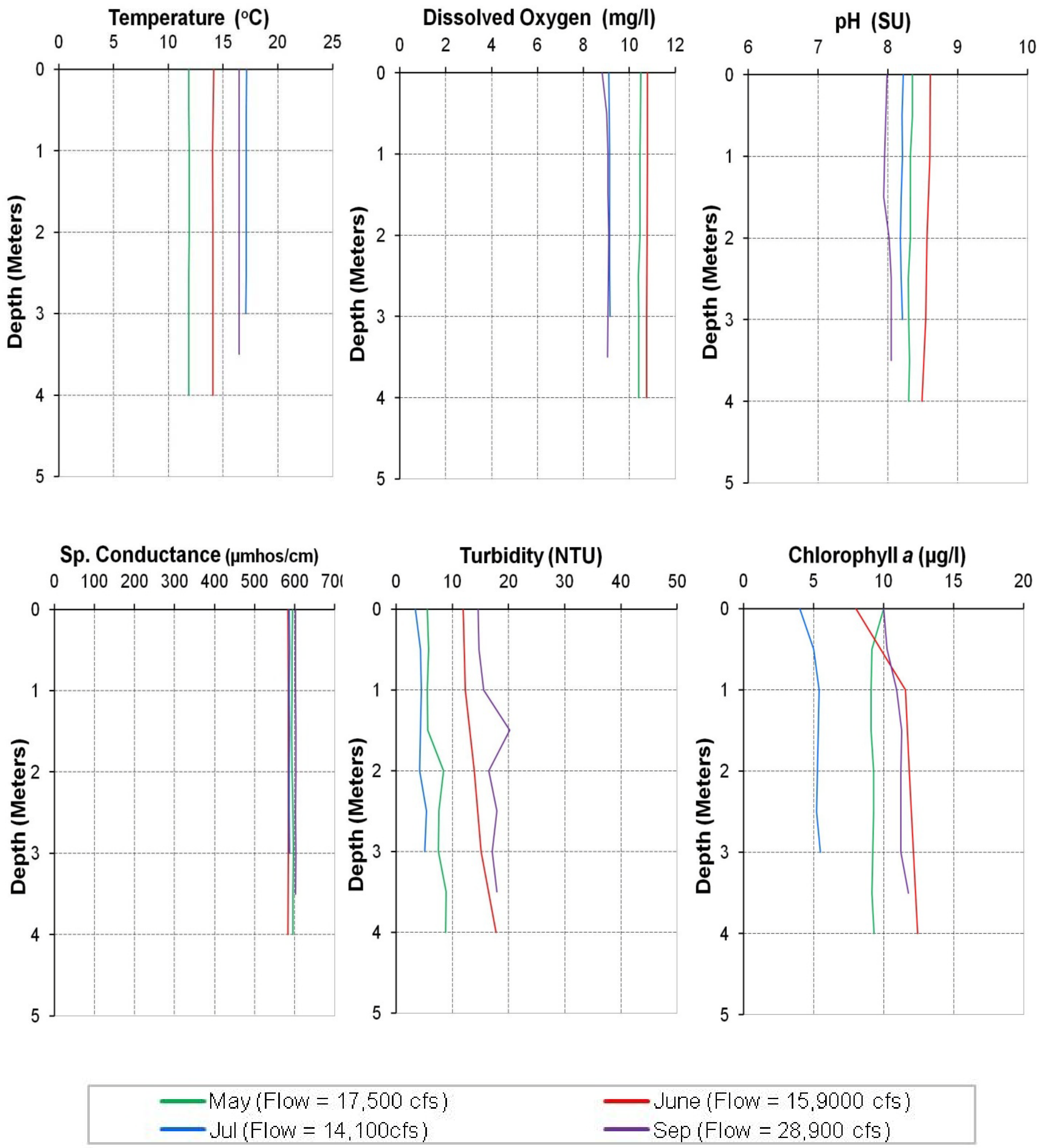

Plate 192. Water temperature, dissolved oxygen, pH, specific conductance, turbidity, and chlorophyll *a* depth profiles for the Missouri River compiled from data collected at the Lake Oahe inflow site at Bismarck, ND (i.e., OAHNFMORR1) during 2010.

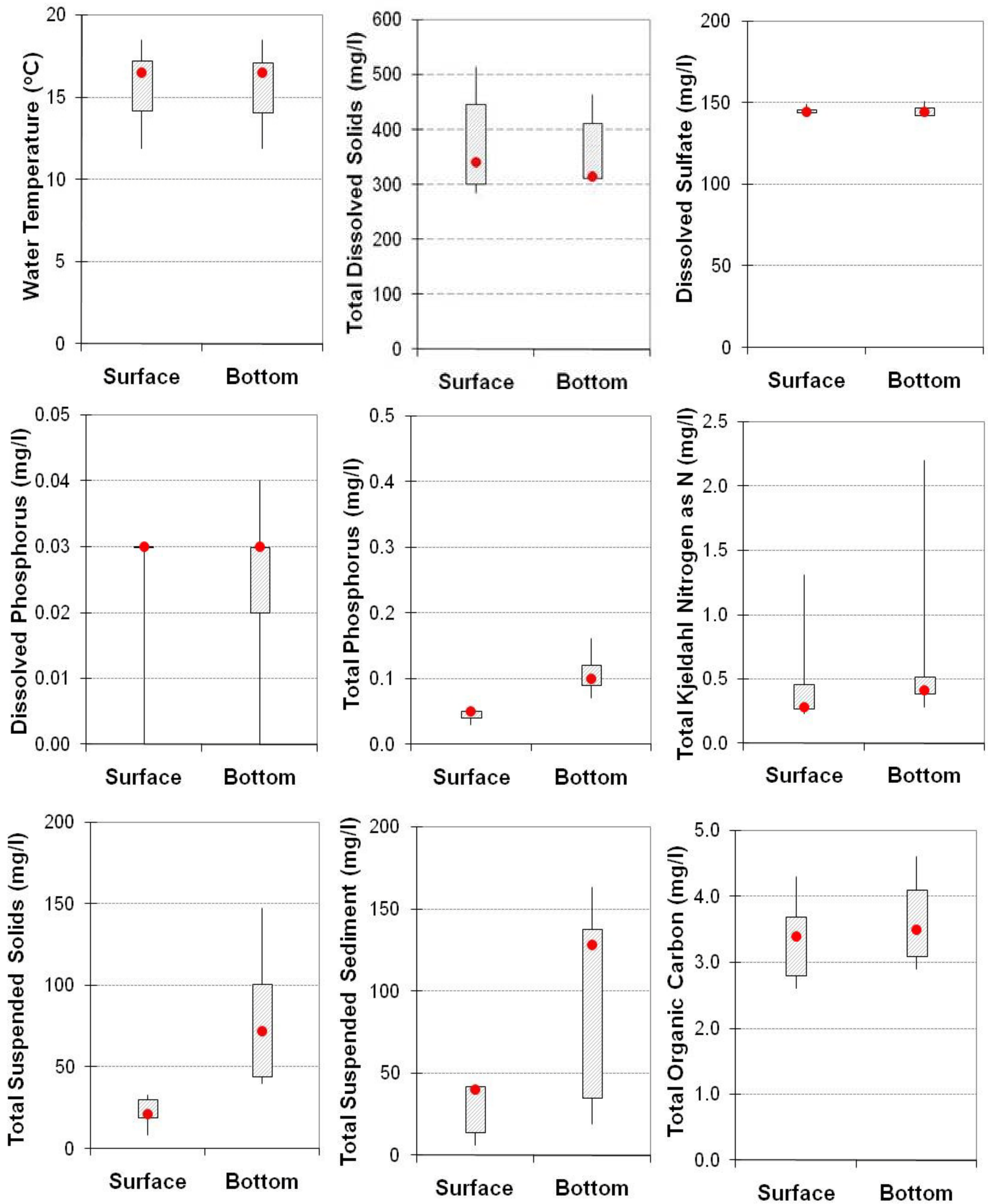

Plate 193. Box plots comparing paired surface and bottom water temperature, total dissolved solids, dissolved sulfate, dissolved phosphorus, total phosphorus, total Kjeldahl nitrogen, total suspended solids, total suspended sediment, and total organic carbon measurements taken in the Missouri River at site OAHNFMORR1 during 2010.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

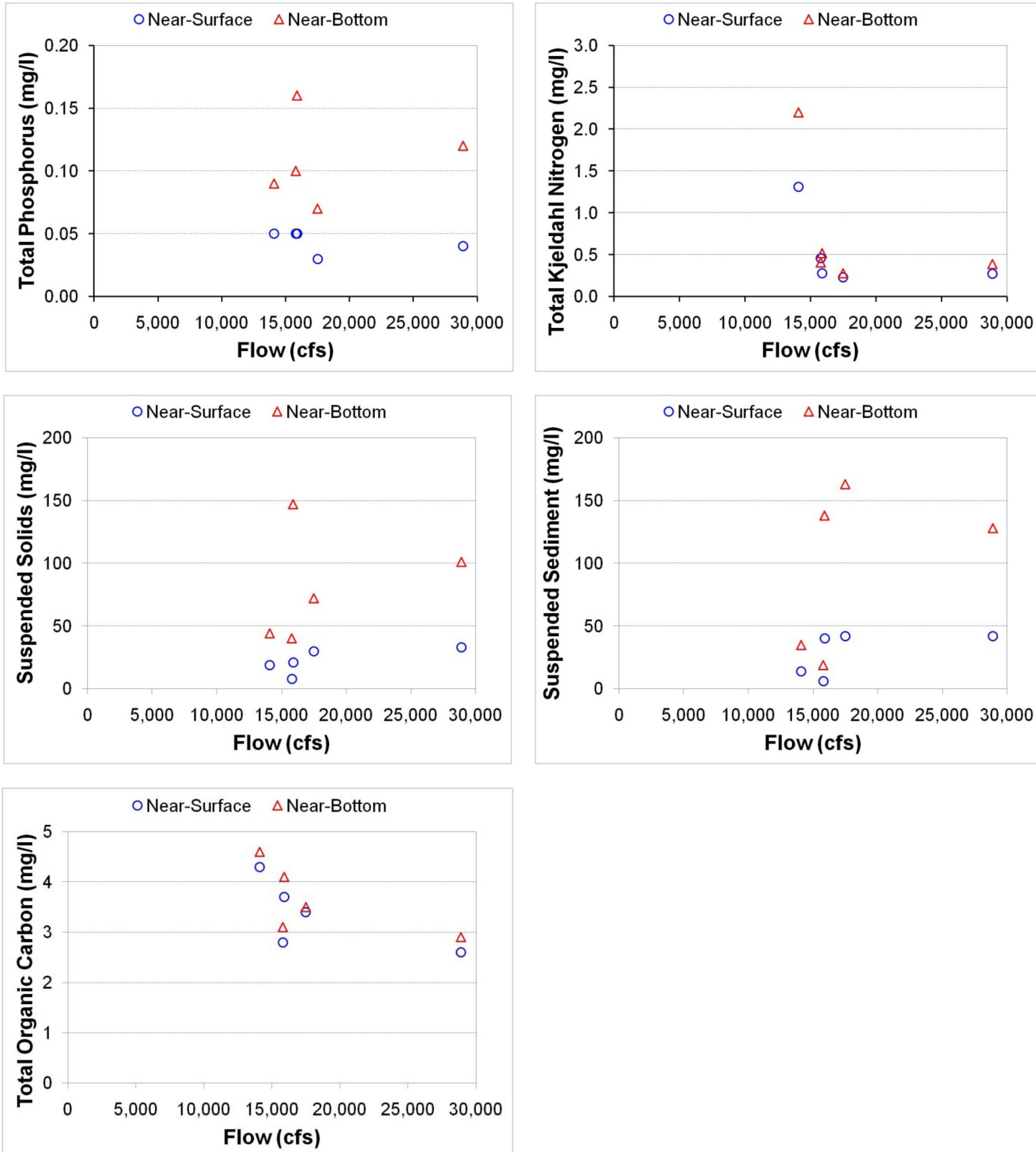

Plate 194. Comparison of flow and measured near-surface and near-bottom concentrations of total phosphorus, total Kjeldahl nitrogen, total suspended solids, total suspended sediment, and total organic carbon in the Missouri River at Bismarck, ND (i.e., site OAHNFMORR1).

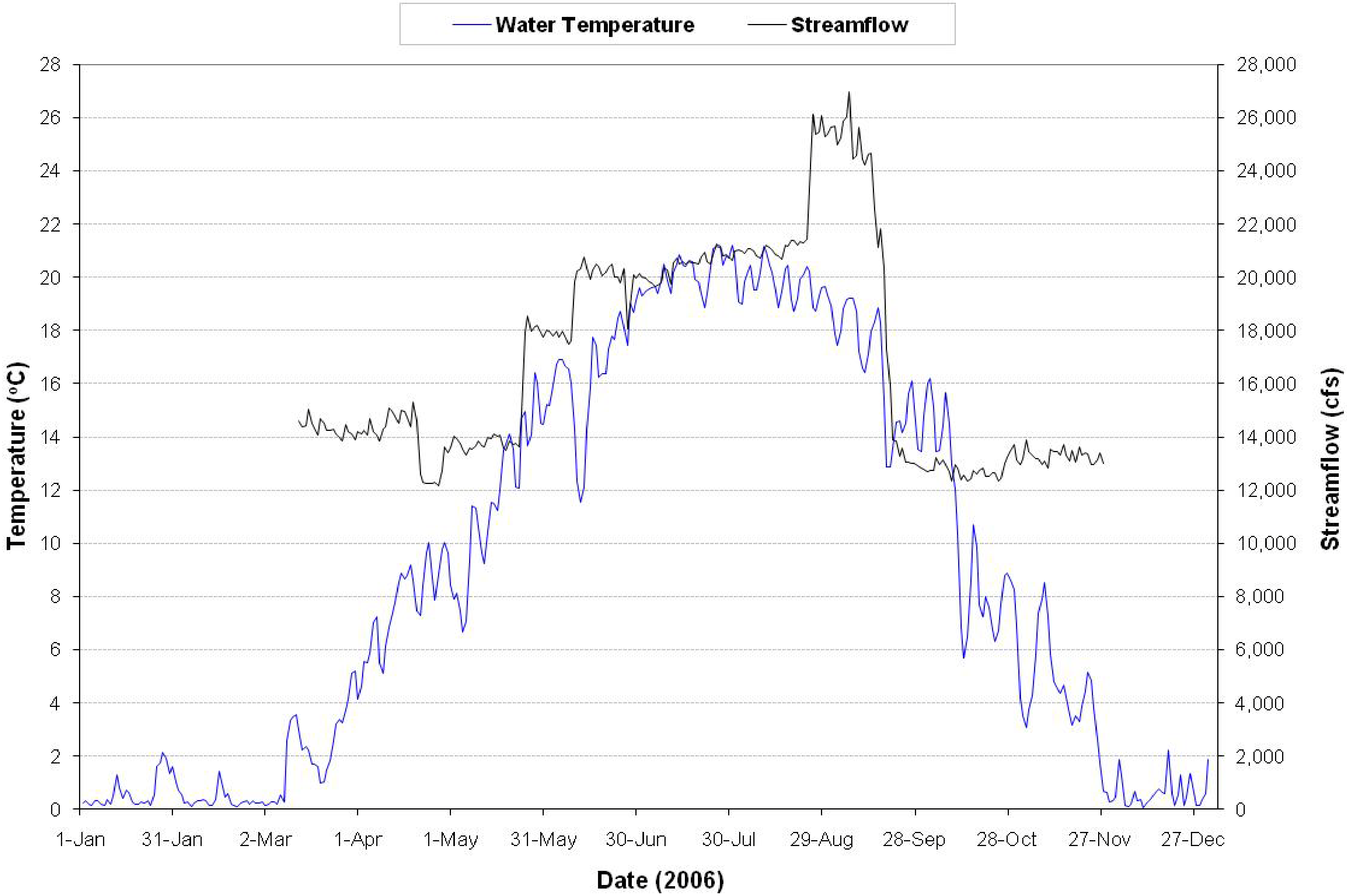

Plate 195. Mean daily water temperature and discharge of the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) for 2006. Mean daily temperatures and discharges based on hourly measurements recorded on the Missouri River at Bismarck, North Dakota (USGS gaging station 06342500).

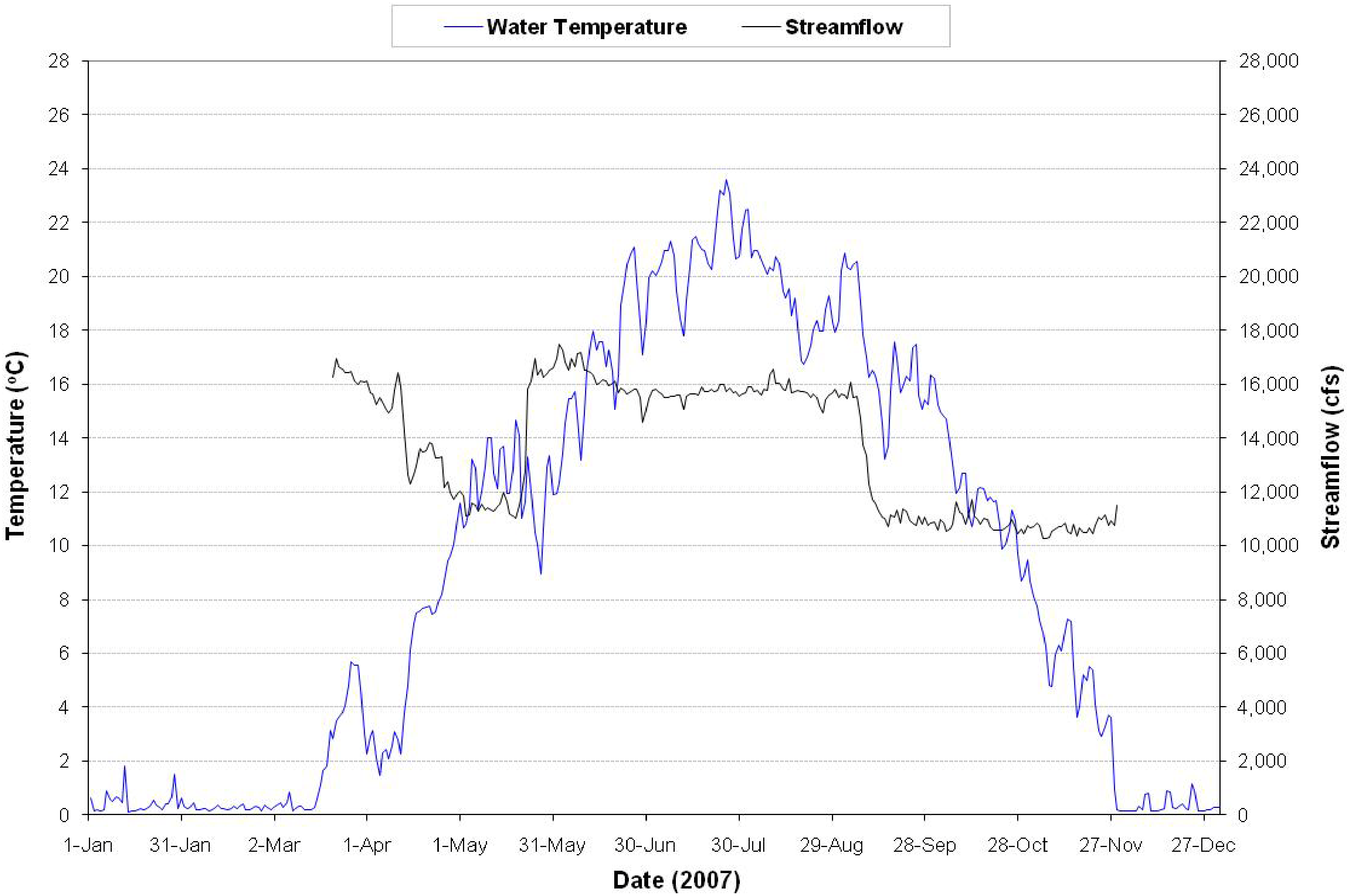

Plate 196. Mean daily water temperature and discharge of the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) for 2007. Mean daily temperatures and discharges based on hourly measurements recorded on the Missouri River at Bismarck, North Dakota (USGS gaging station 06342500).

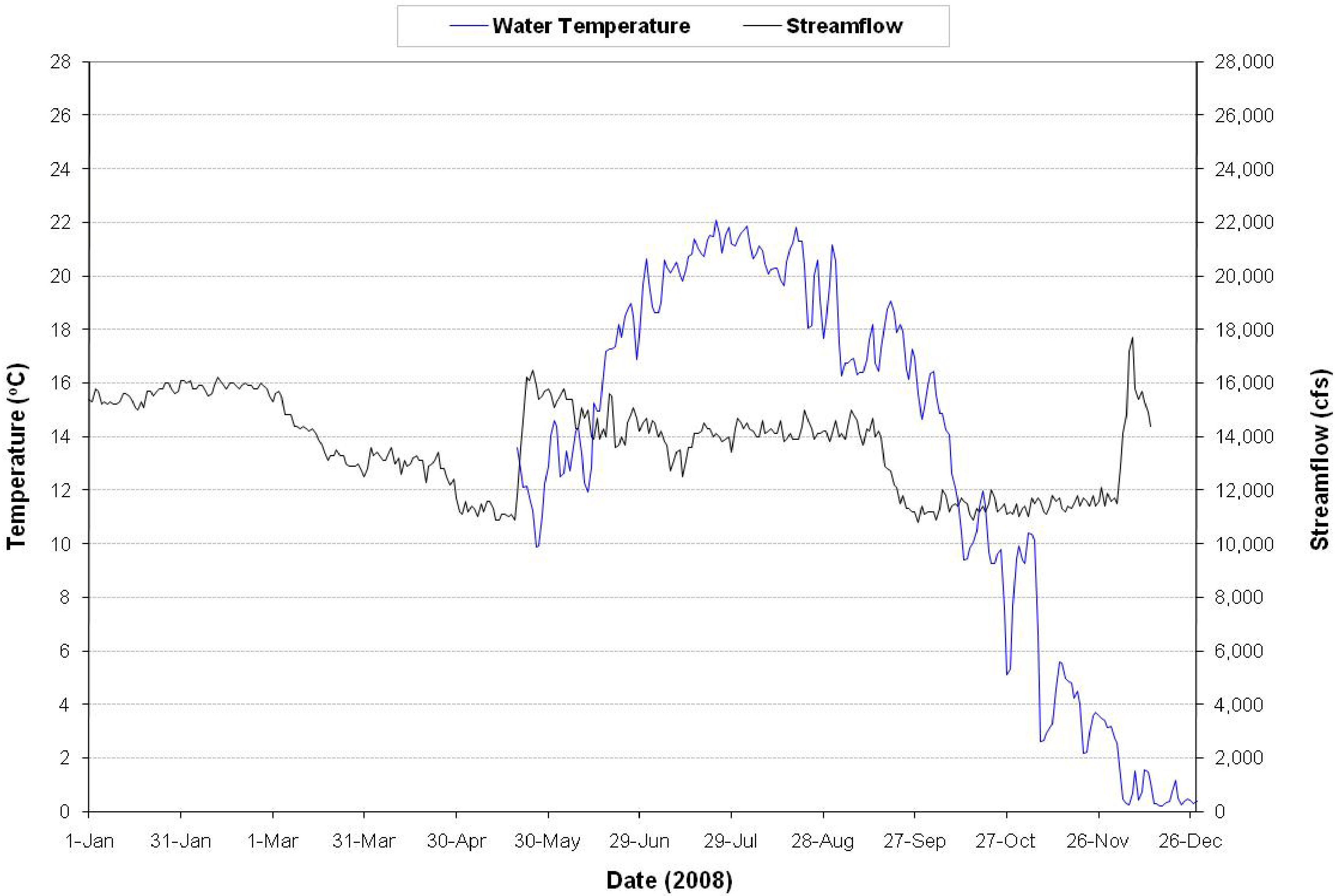

Plate 197. Mean daily water temperature and discharge of the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) for 2008. Mean daily temperatures and discharges based on hourly measurements recorded on the Missouri River at Bismarck, North Dakota (USGS gaging station 06342500).

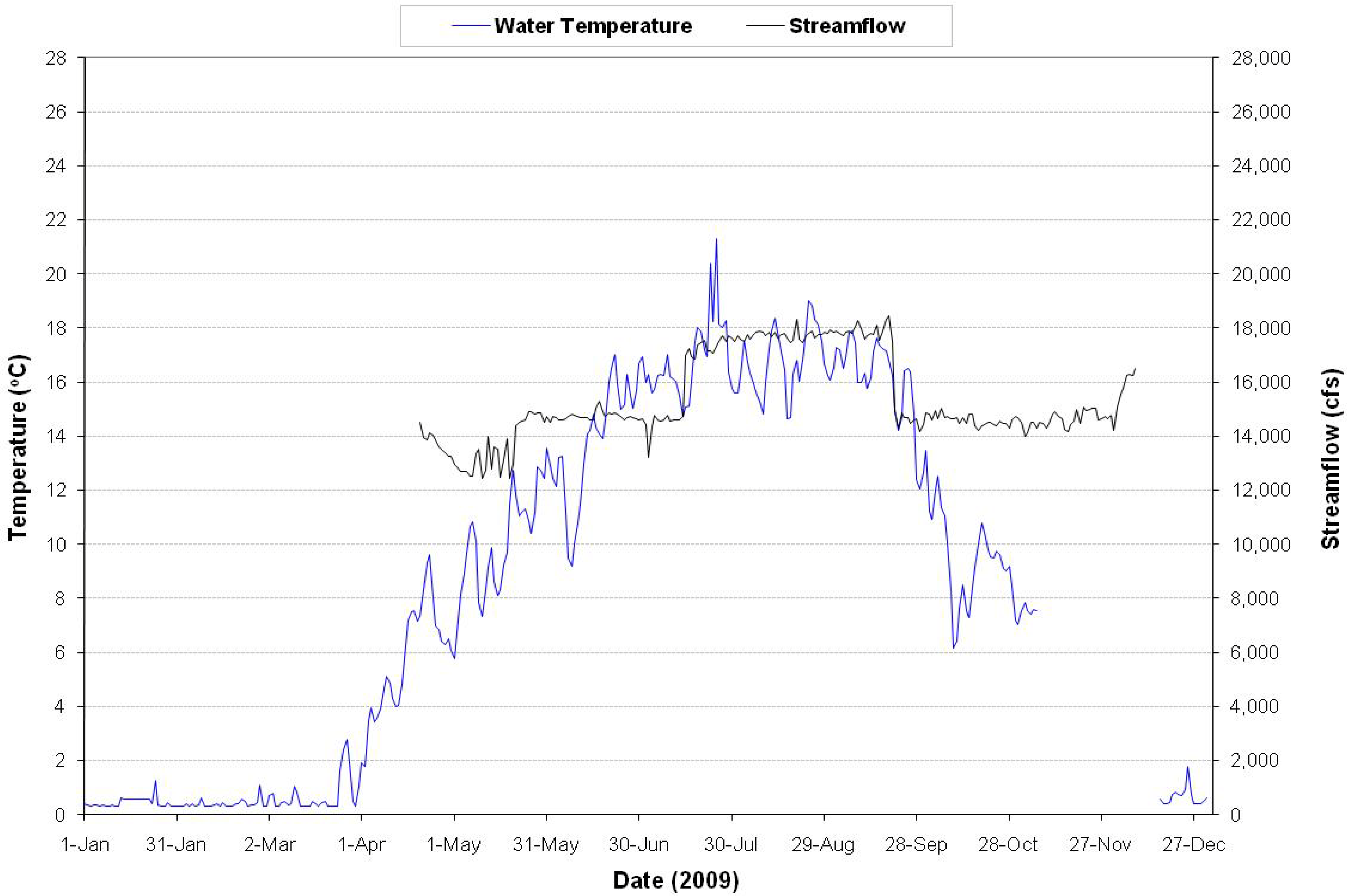

Plate 198. Mean daily water temperature and discharge of the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) for 2009. Mean daily temperatures and discharges based on hourly measurements recorded on the Missouri River at Bismarck, North Dakota (USGS gaging station 06342500).

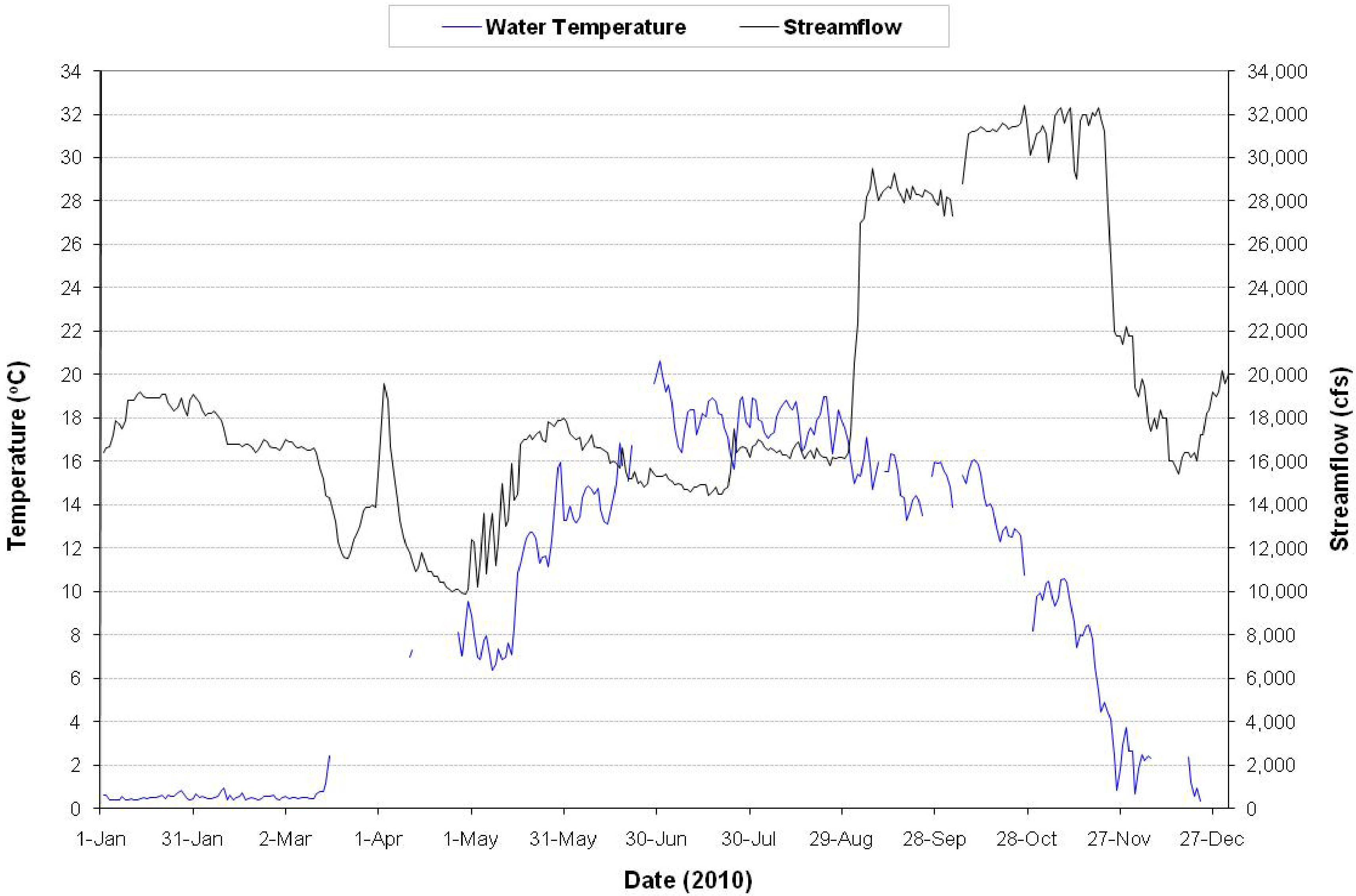

Plate 199. Mean daily water temperature and discharge of the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) for 2010. Mean daily temperatures and discharges based on hourly measurements recorded on the Missouri River at Bismarck, North Dakota (USGS gaging station 06342500).

Plate 200. Summary of monthly water quality conditions monitored on water discharged through Oahe Dam (i.e., site OAHPP1) during the 5-year period of 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[(A)]	No. of Obs.	Mean[(B)]	Median	Min.	Max.	State WQS Criteria[(C)]	No. of WQS Exceedances	Percent WQS Exceedance
Dam Discharge (cfs)	1	49	22,627	22,302	0	56,047	-----	-----	-----
Water Temperature (°C)	0.1	48	11.3	11.8	0.8	23.2	18.3[(1,5)]	11	23%
Dissolved Oxygen (mg/l)	0.1	48	10.4	10.2	7.1	15.0	5[(3,6)], 6[(1,6,8)], 7[(1,6,8)]	0	0%
Dissolved Oxygen (% Sat.)	0.1	48	96.4	97.4	72.3	112.1	-----	-----	-----
pH (S.U.)	0.1	38	8.2	8.2	7.3	8.8	6.5[(1,2,6)], 9.0[(1,2,5)], 9.5[(4,5)]	0	0%
Specific Conductance (umhos/cm)	1	48	692	693	357	816	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	41	372	363	210	666	-----	-----	-----
Turbidity (NTU)	1	40	4	2	n.d.	50	-----	-----	-----
Alkalinity, Total (mg/l)	7	49	160	161	140	202	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	47	3.3	3.1	1.2	5.9	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	49	8	8	n.d.	19	-----	-----	-----
Chloride, Dissolved (mg/l)	1	37	11	11	6	22	175[(1,5)], 438[(2,5)] 100[(1,7)], 250[(2,7)]	0	0%
Dissolved Solids, Total (mg/l)	5	49	481	466	360	850	1,750[(2,5)], 3,500[(4,5)] 1,000[(2,7)], 2,000[(4,7)]	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	49	-----	n.d.	n.d.	0.31	3.8 [(1,5,9)], 1.7 [(1,7,9)]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	49	-----	0.3	n.d.	1.8	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	49	-----	n.d.	n.d.	0.20	10[(2,5)]	0	0%
Nitrogen, Total (mg/l)	0.1	49	0.4	0.4	n.d.	1.8	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	47	-----	n.d.	n.d.	0.20	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	49	-----	0.02	n.d.	0.29	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	49	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	49	196	198	163	222	875[(2,5)], 500[(2,7)]	0	0%
Suspended Solids, Total (mg/l)	4	49	-----	n.d.	n.d.	73	53[(1,5)], 30[(1,7)]	1, 1	2%, 2%

n.d. = Not detected, b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

Plate 201. Summary of annual metals and pesticide levels monitored on water discharged through Oahe Dam (i.e., site OAHPP1) during the 5-year period of 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Aluminum, Total (ug/l)	25	4	-----	79	n.d.	110	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Antimony, Total (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	5.6[3]	0	0%
Arsenic, Dissolved (ug/l)	1	4	1	1	1	2	340[1], 150[2]	0, 0	0%
Arsenic, Total (ug/l)	1	4	1	1	1	2	0.018[3]	4	100%
Barium, Dissolved (ug/l)	5	4	41	42	36	43	-----	-----	-----
Barium, Total (ug/l)	5	4	44	44	39	50	-----	-----	-----
Beryllium, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Beryllium, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	4[3]	0	0%
Cadmium, Dissolved (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	4.2[1], 0.42[2]	0	0%
Cadmium, Total (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	5[3]	0	0%
Chromium, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	n.d.	1,058[1], 138[2]	0	0%
Chromium, Total (ug/l)	10	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Copper, Dissolved (ug/l)	2	6	-----	n.d.	n.d.	3	27[1], 17[2],	0	0%
Copper, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	1,300[3]	0	0%
Hardness, Total (mg/l)	0.4	5	221	213	209	240	-----	-----	-----
Iron, Dissolved (ug/l)	40	8[A]	-----	n.d.	n.d.	21	-----	-----	-----
Iron, Total (ug/l)	40	16[A]	139	62	n.d.	540	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	146[1], 5.7[2]	0	0%
Lead, Total (ug/l)	0.5	4	1.3	1.0	0.9	2.1	-----	-----	-----
Manganese, Dissolved (ug/l)	2	16[A]	-----	n.d.	n.d.	16	-----	-----	-----
Manganese, Total (ug/l)	2	16[A]	19	12	n.d.	66	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	6	-----	n.d.	n.d.	n.d.	1.4[1]	0	0%
Mercury, Total (ug/l)	0.05	6	-----	n.d.	n.d.	n.d.	0.77[2], 0.05[3]	0	0%
Nickel, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	n.d.	888[1], 99[2]	0	0%
Nickel, Total (ug/l)	10	4	-----	n.d.	n.d.	n.d.	610[3]	0	0%
Selenium, Total (ug/l)	1	4	-----	2	n.d.	2	4.6[2], 170[3]	0	0%
Silver, Dissolved (ug/l)	1	6	-----	n.d.	n.d.	n.d.	13[1]	0	0%
Silver, Total (ug/l)	1	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Total (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	0.24[3]	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	5	-----	n.d.	n.d.	11	224[1,2]	0	0%
Zinc, Total (ug/l)	10	4	-----	n.d.	n.d.	n.d.	7,400[3]	0	0%
Pesticide Scan (ug/l)[D]	0.05[E]	5	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected, b.d. = Criterion below detection limit.

(A) Results for iron (dissolved and total) and manganese (dissolved and total) include some monthly samples.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Acute (CMC) criterion for the protection of freshwater aquatic life.

(2) Chronic (CCC) criterion for the protection of freshwater aquatic life.

(3) Criterion for the protection of human health.

Note: Some of South Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

(E) Detection limits vary by pesticide – 0.05 ug/l is a median detection limit for the pesticides in the pesticide scan.

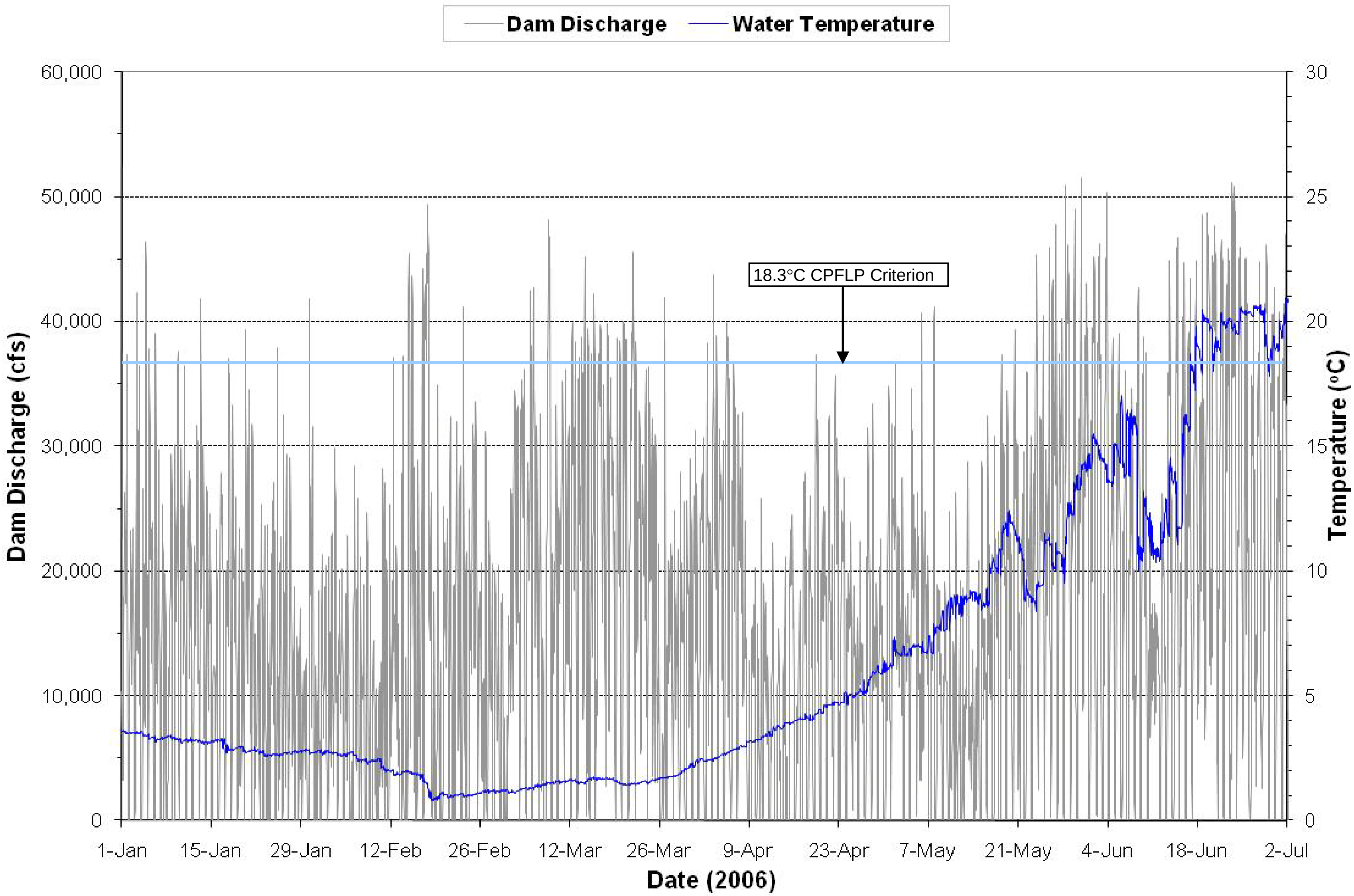

Plate 202. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2006.

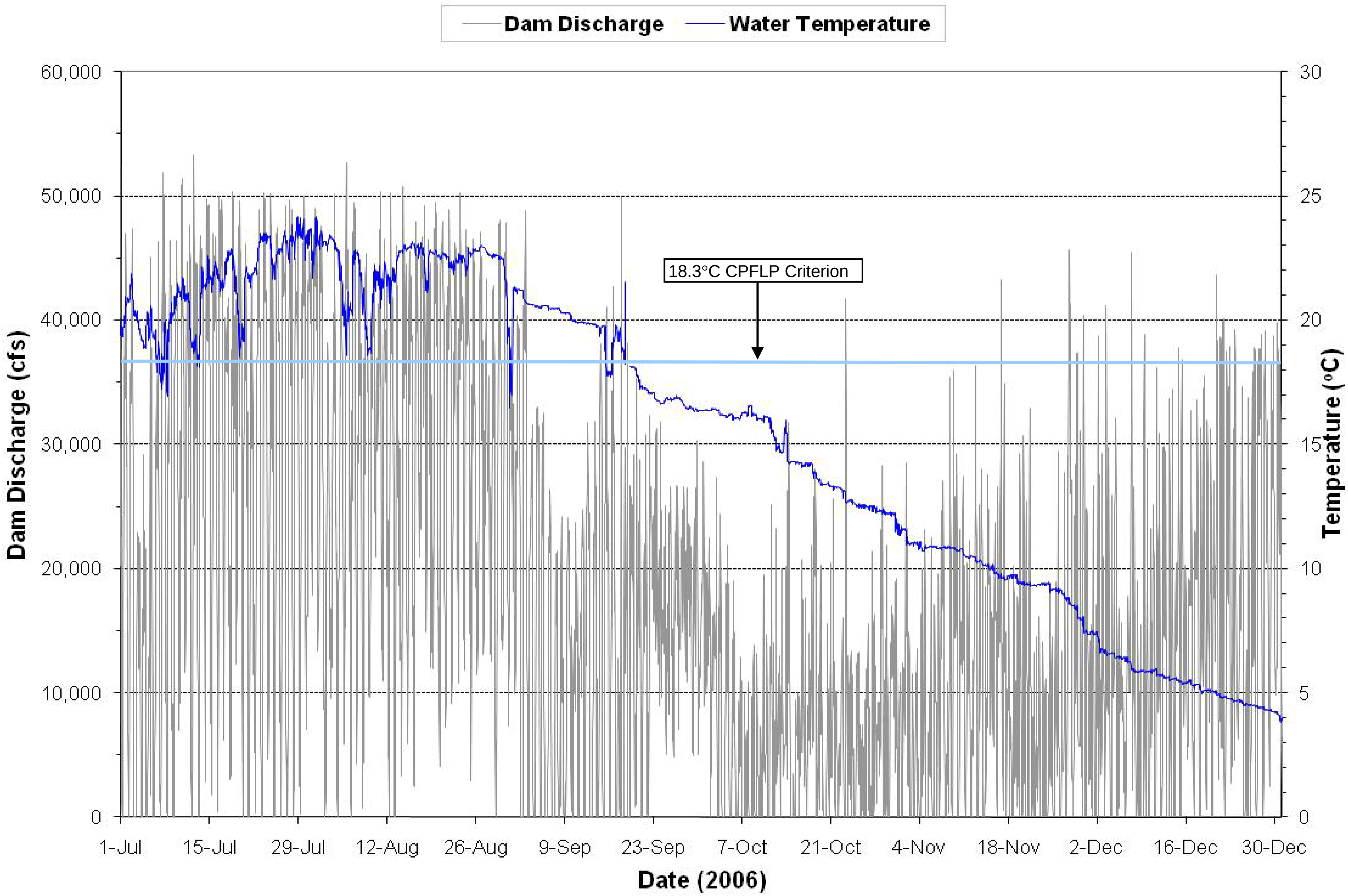

Plate 203. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period July through December 2006.

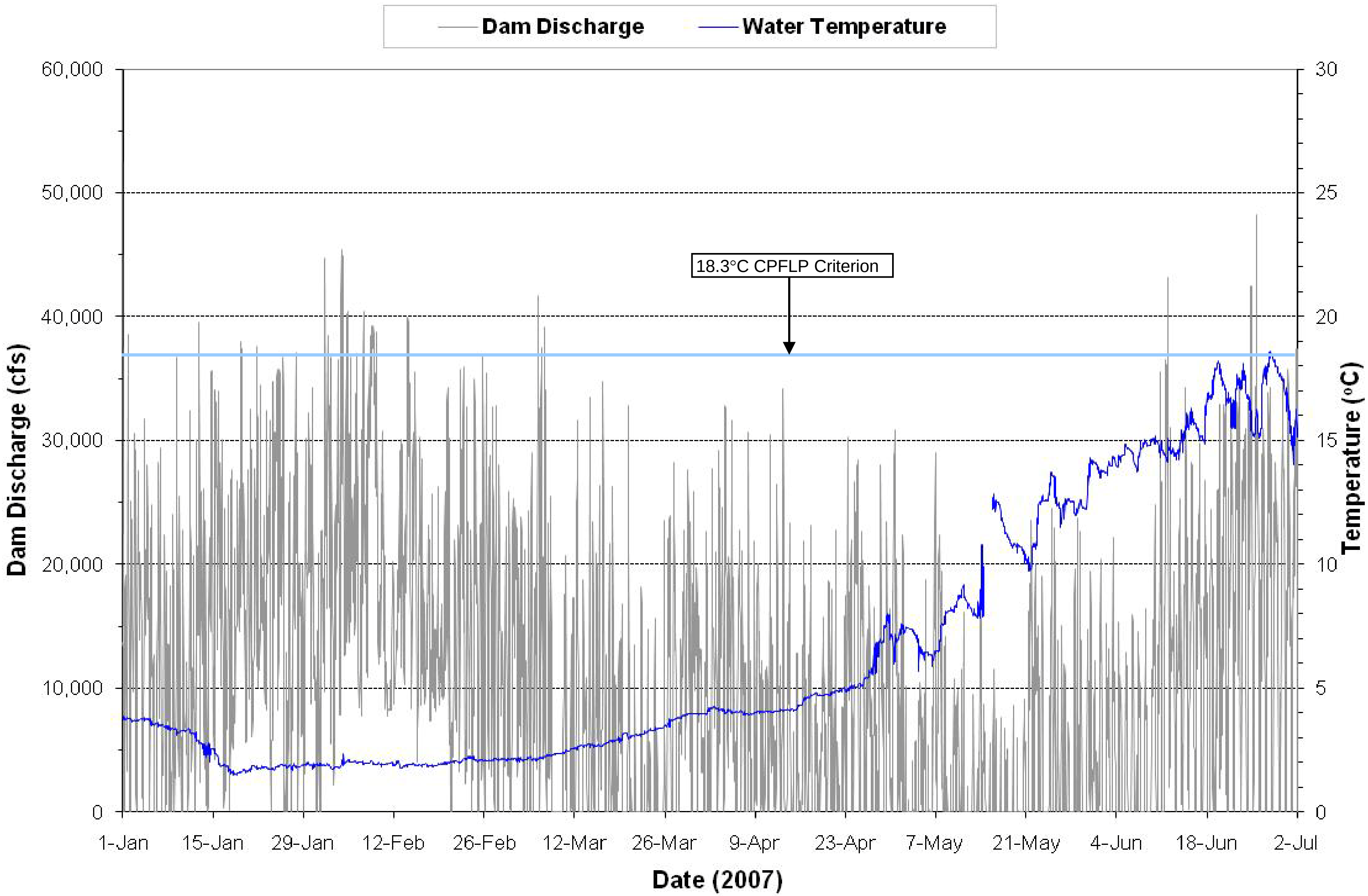

Plate 204. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2007.

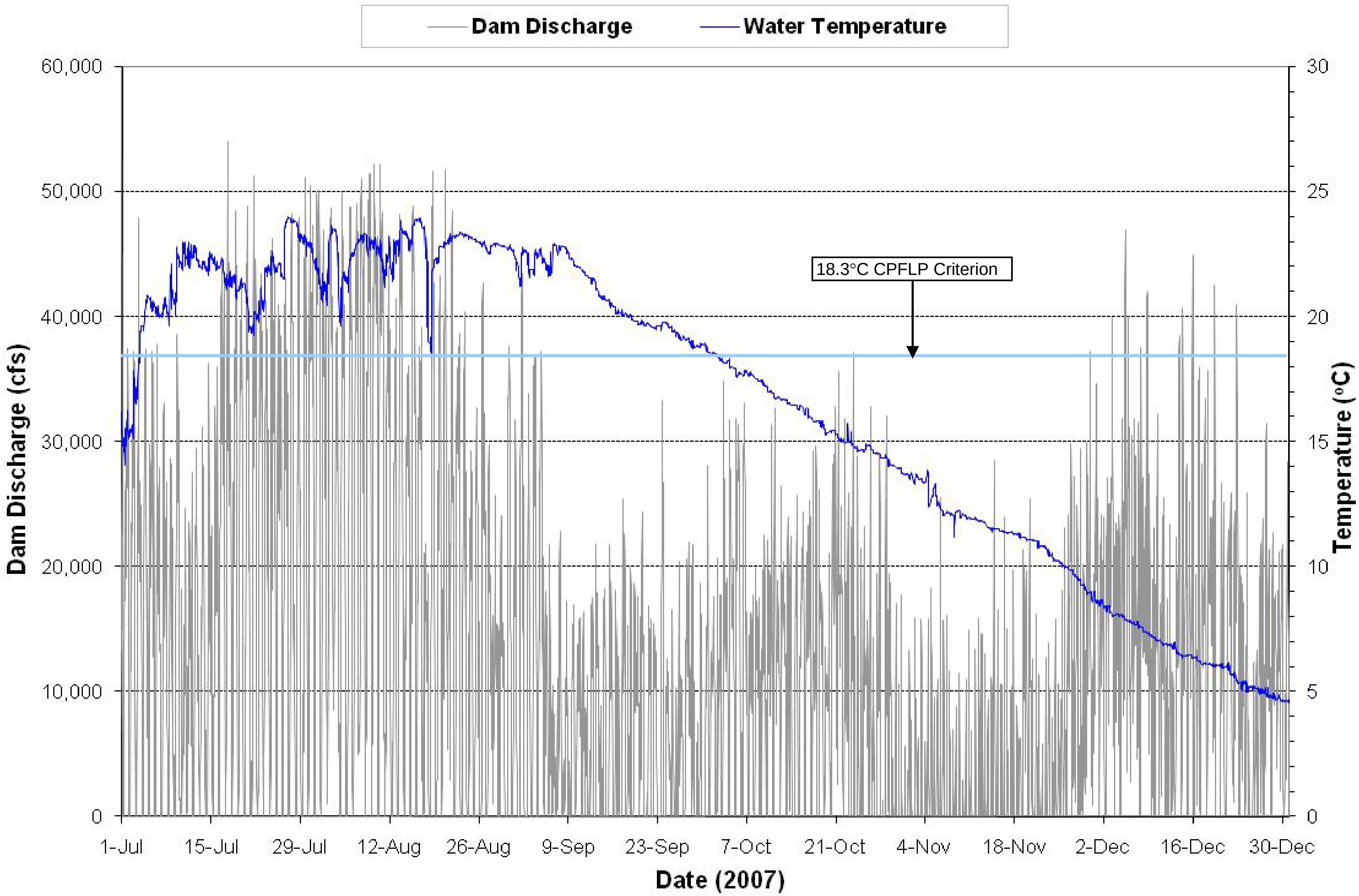

Plate 205. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period July through December 2007.

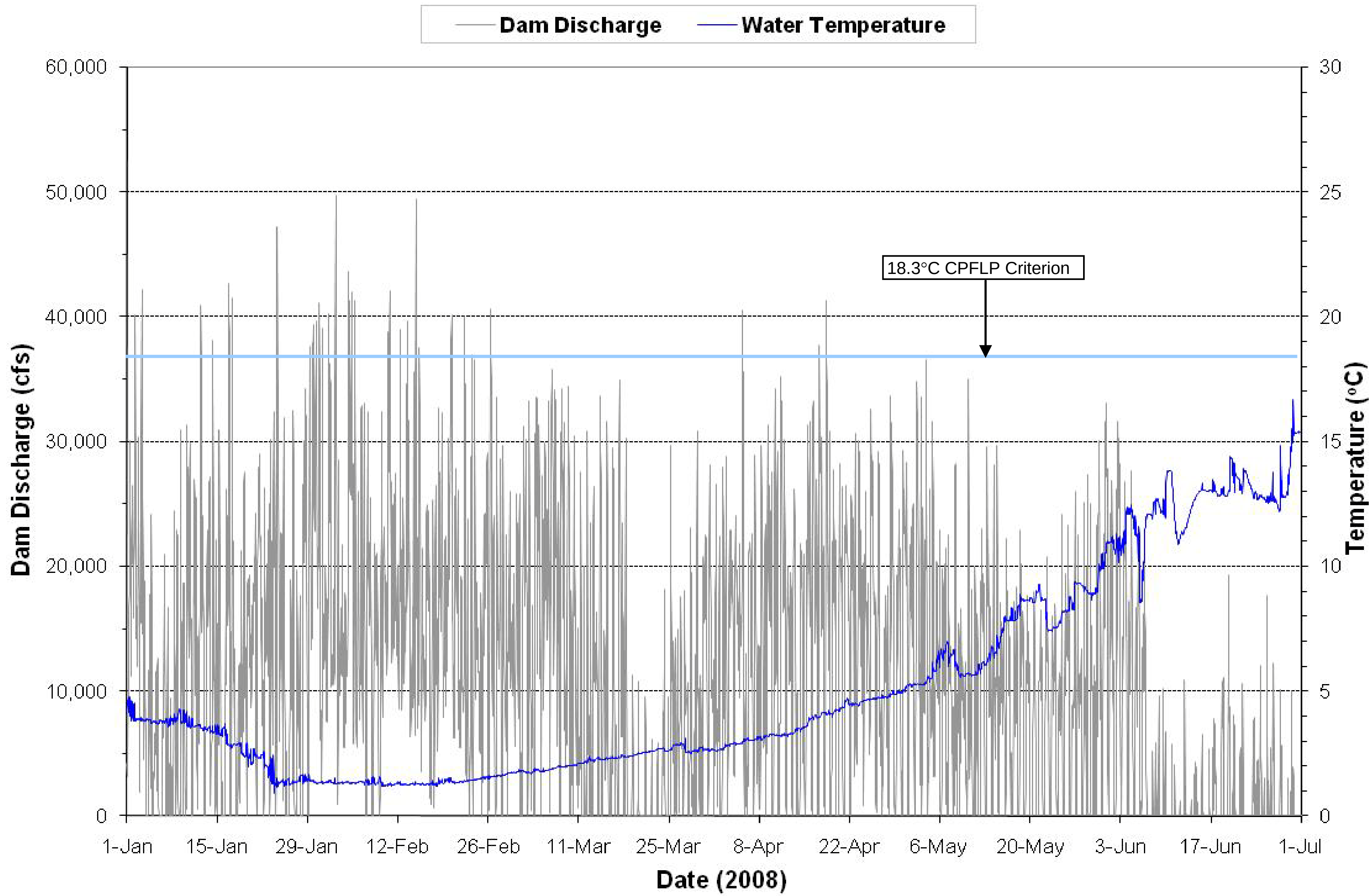

Plate 206. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2008.

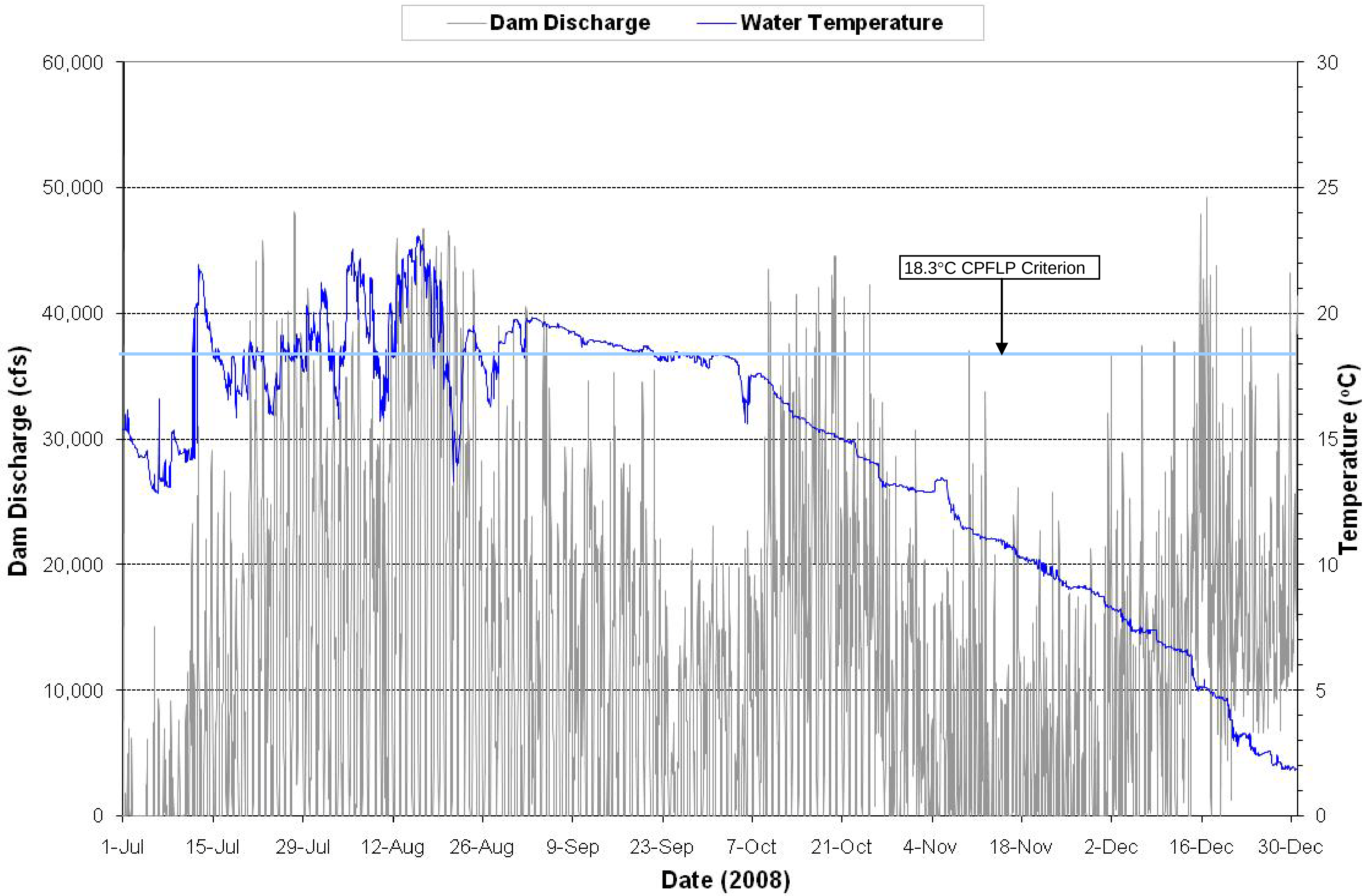

Plate 207. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period July through December 2008.

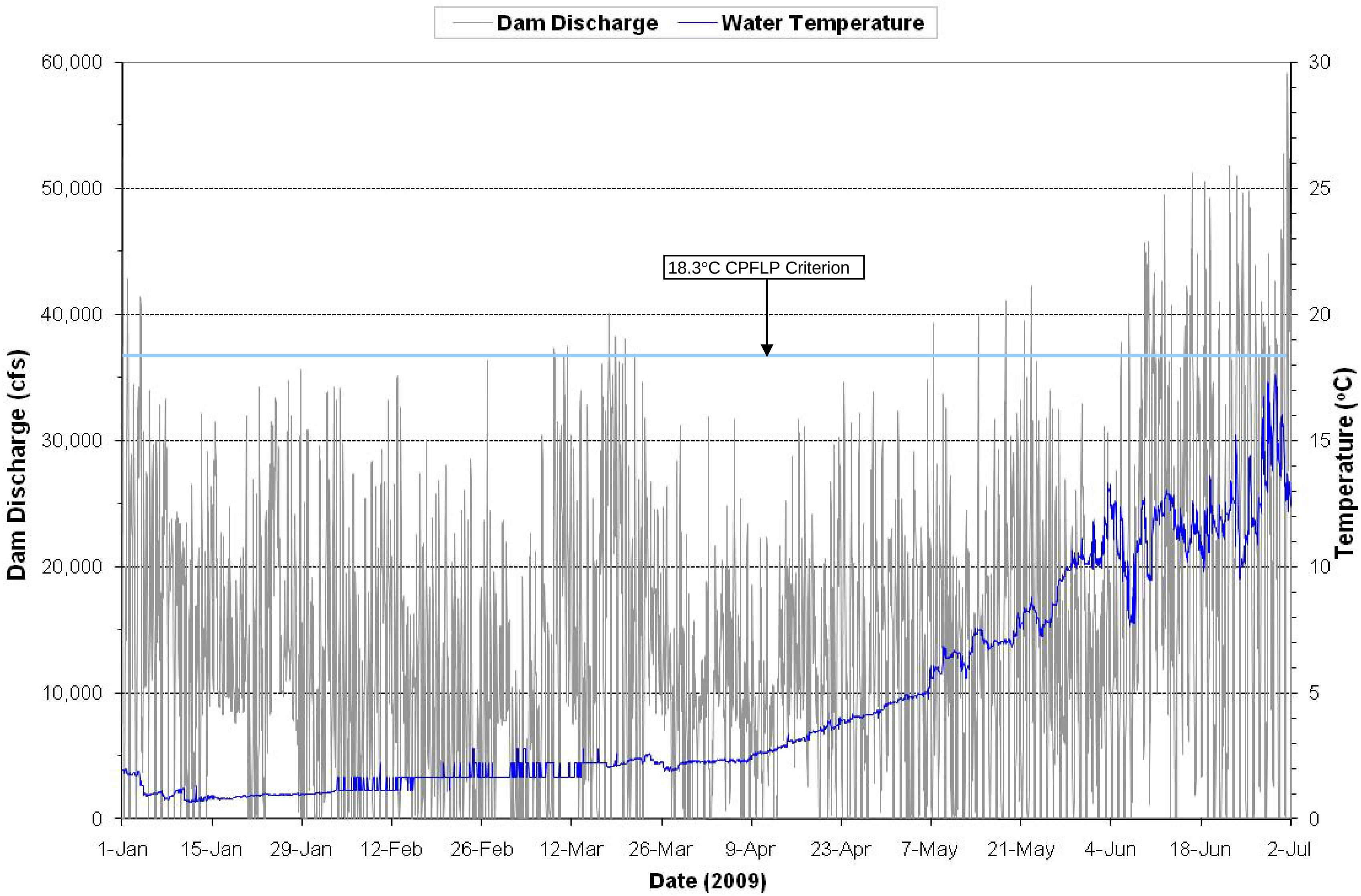

Plate 208. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2009.

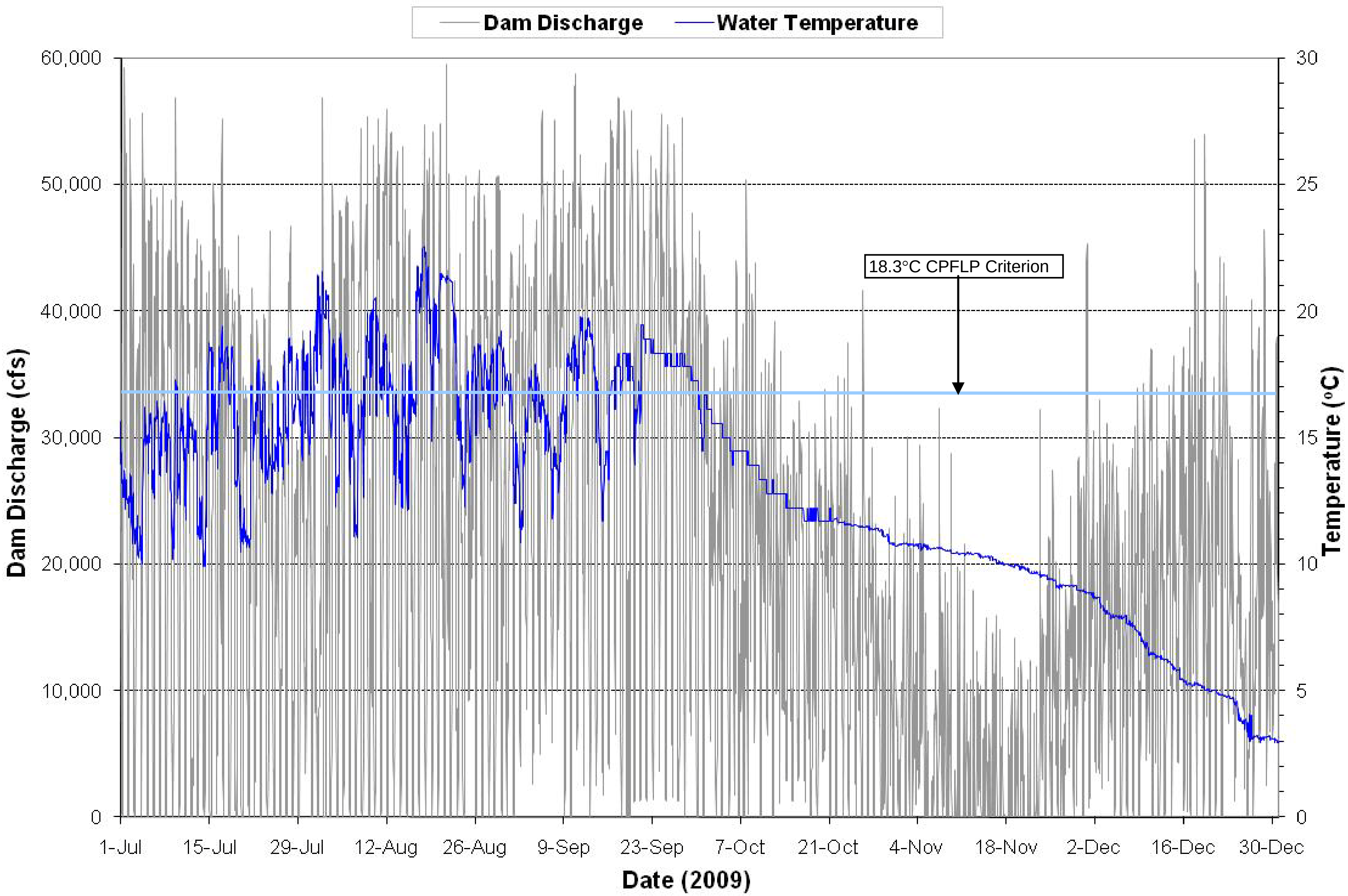

Plate 209. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period July through December 2009.

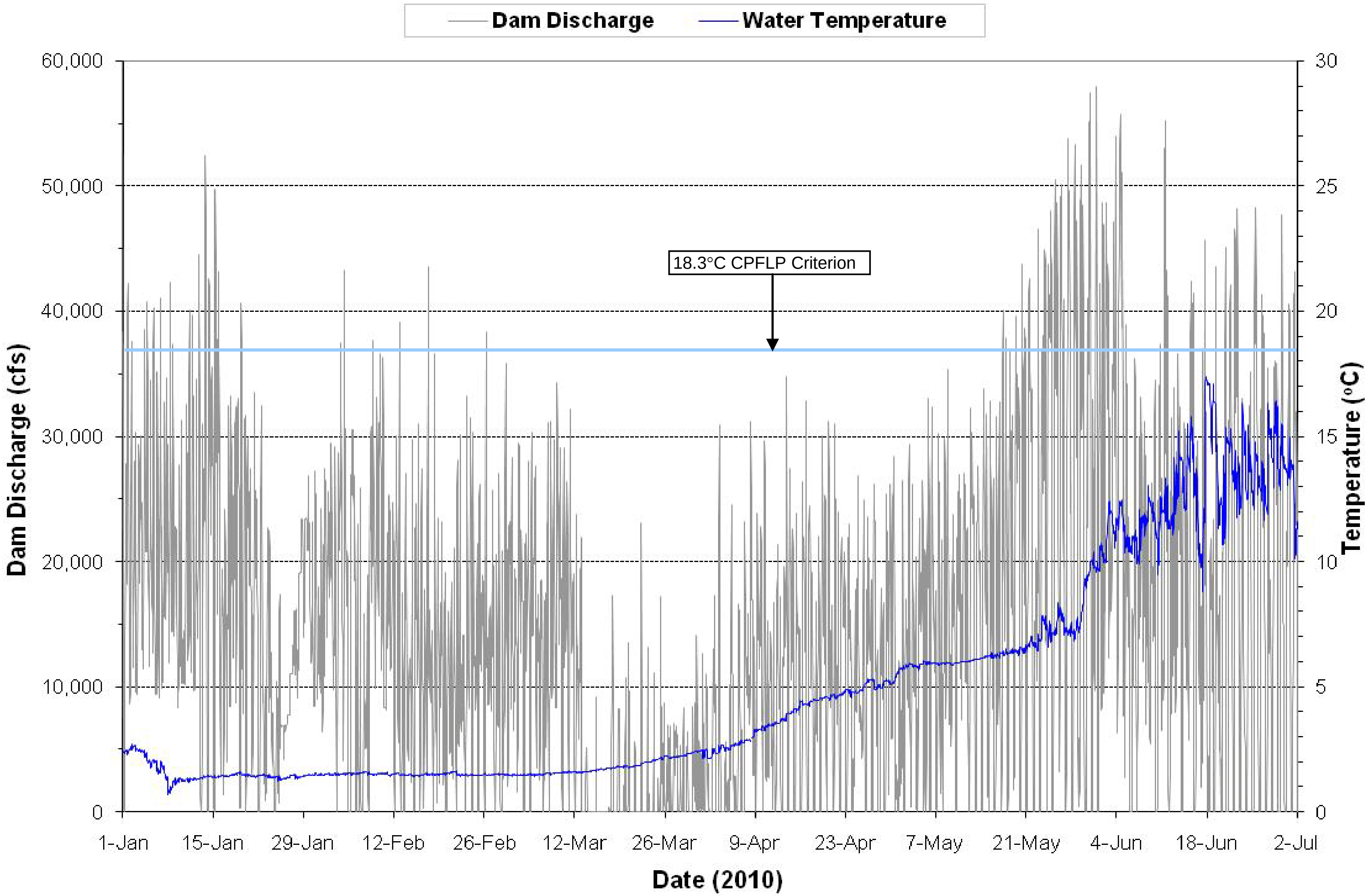

Plate 210. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2010.

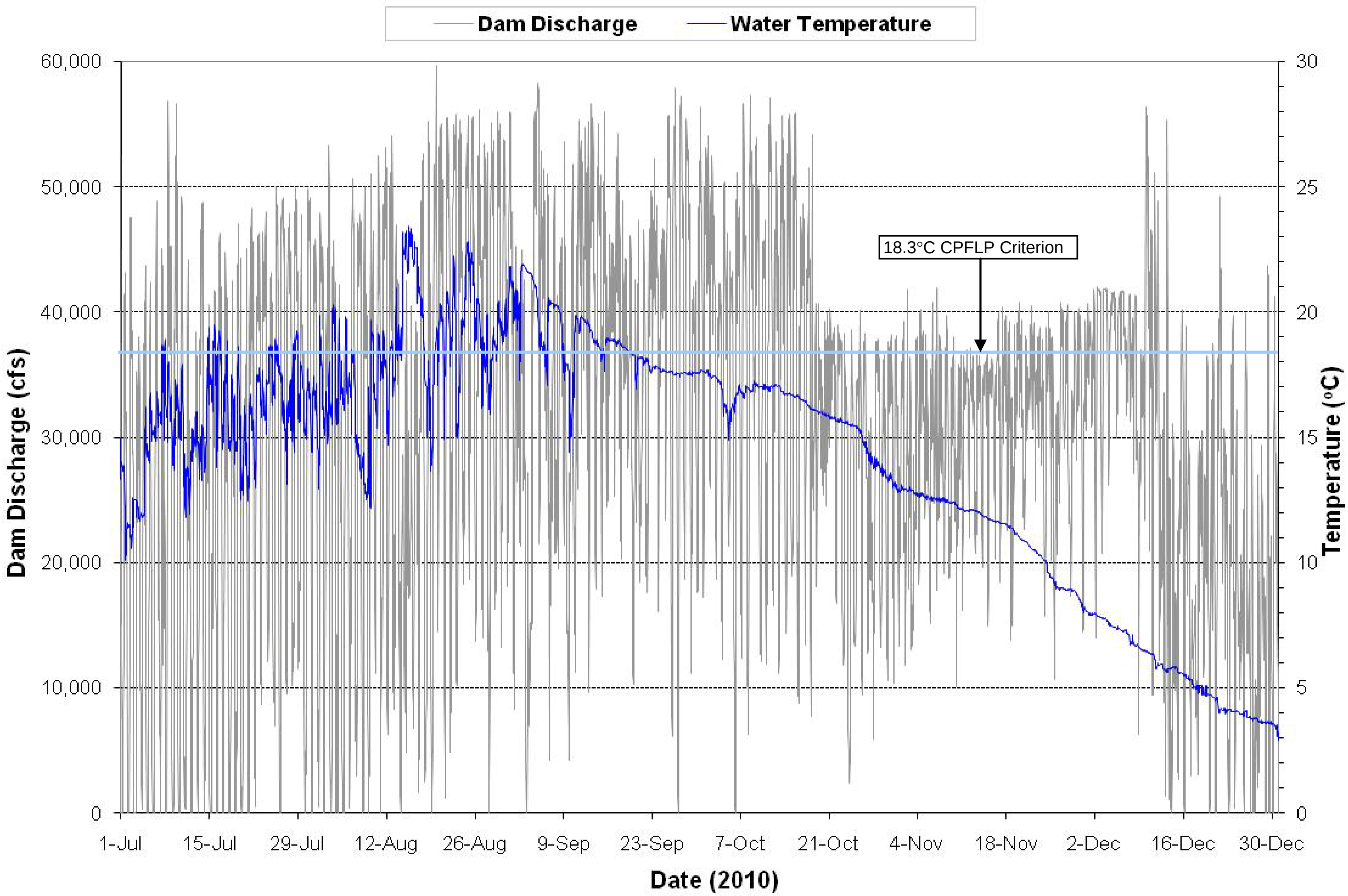

Plate 211. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period July through December 2010.

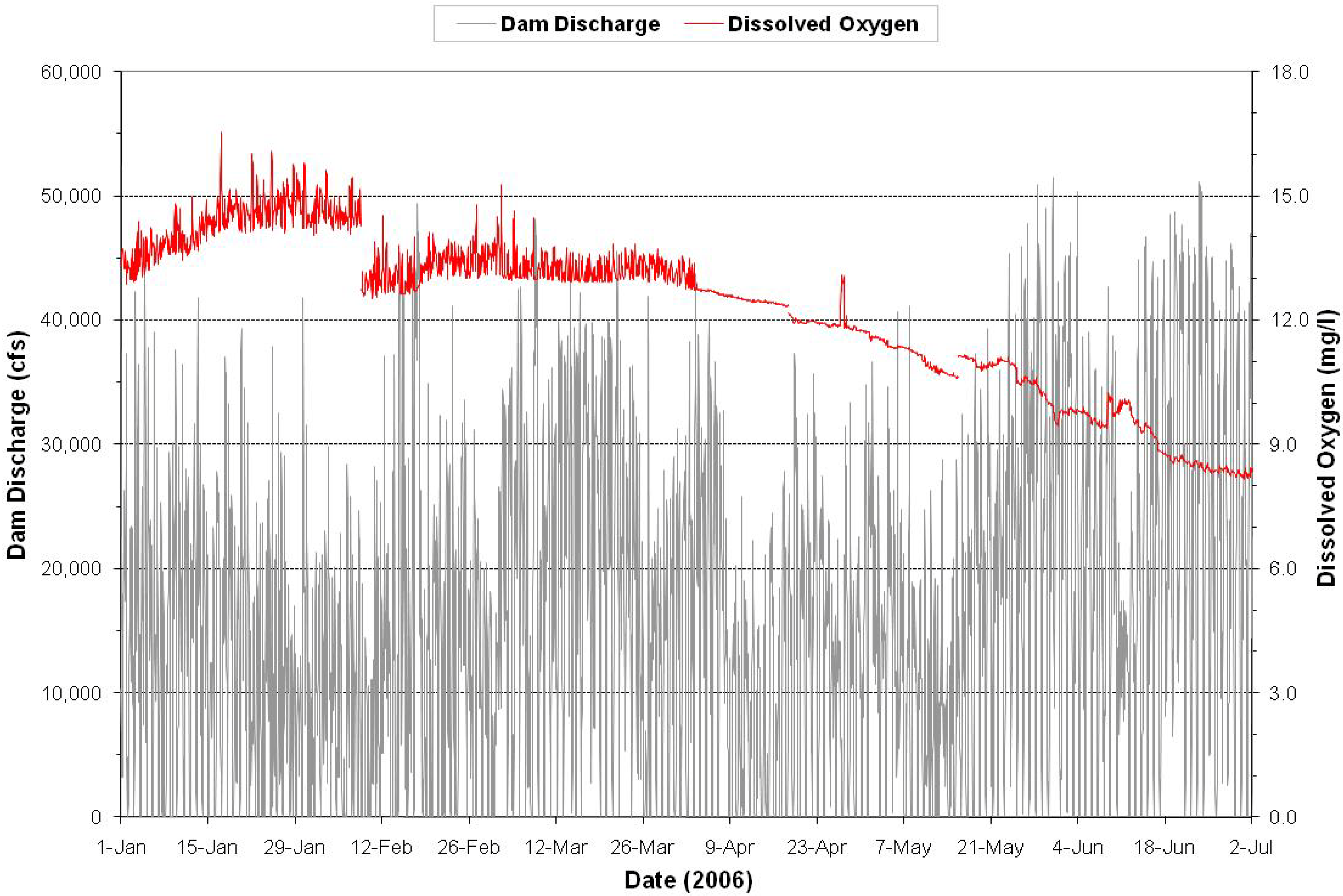

Plate 212. Hourly discharge and dissolved oxygen monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2006.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

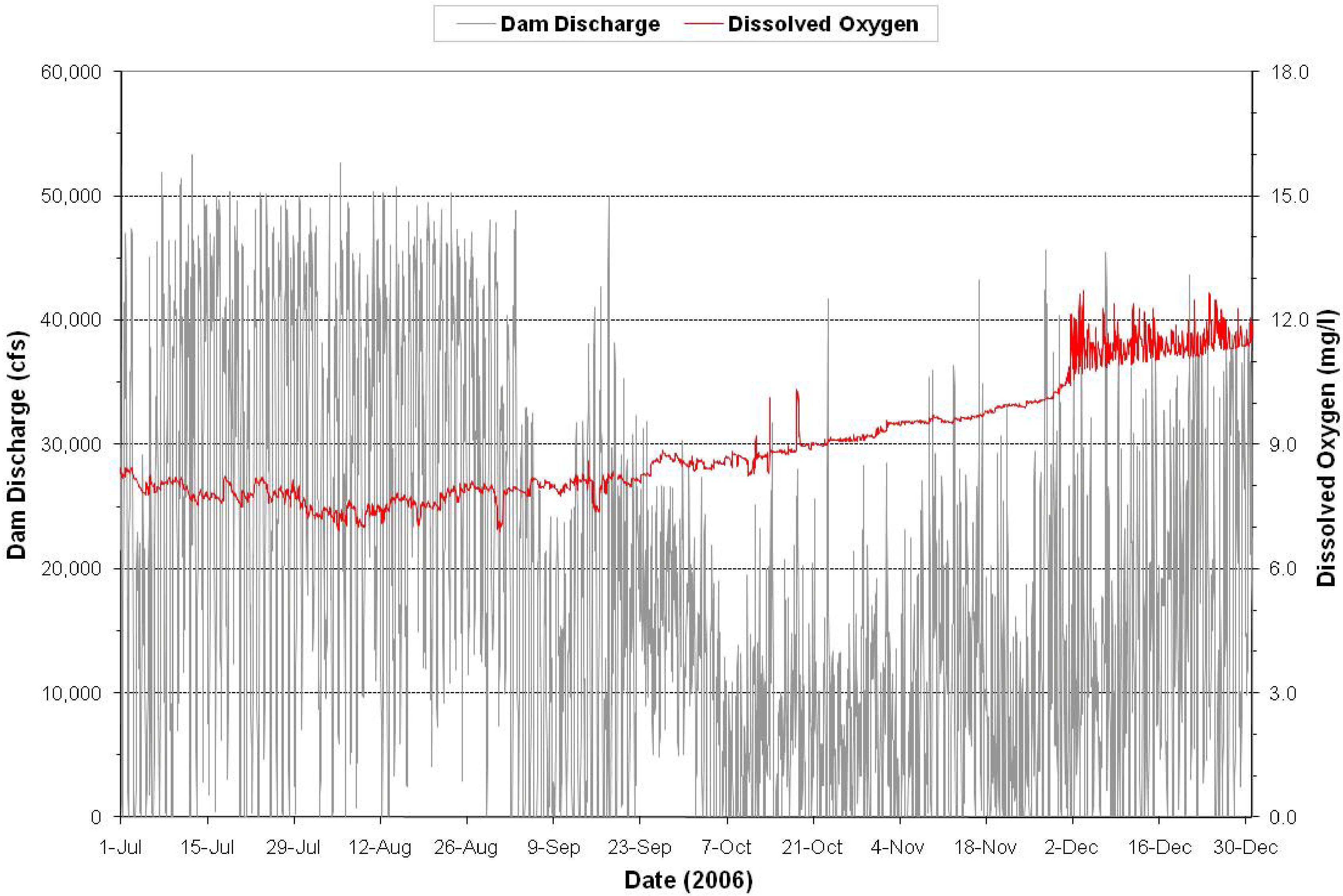

Plate 213. Hourly discharge and dissolved oxygen monitored at the Oahe Powerplant on water discharged through the dam during the period July through December 2006.

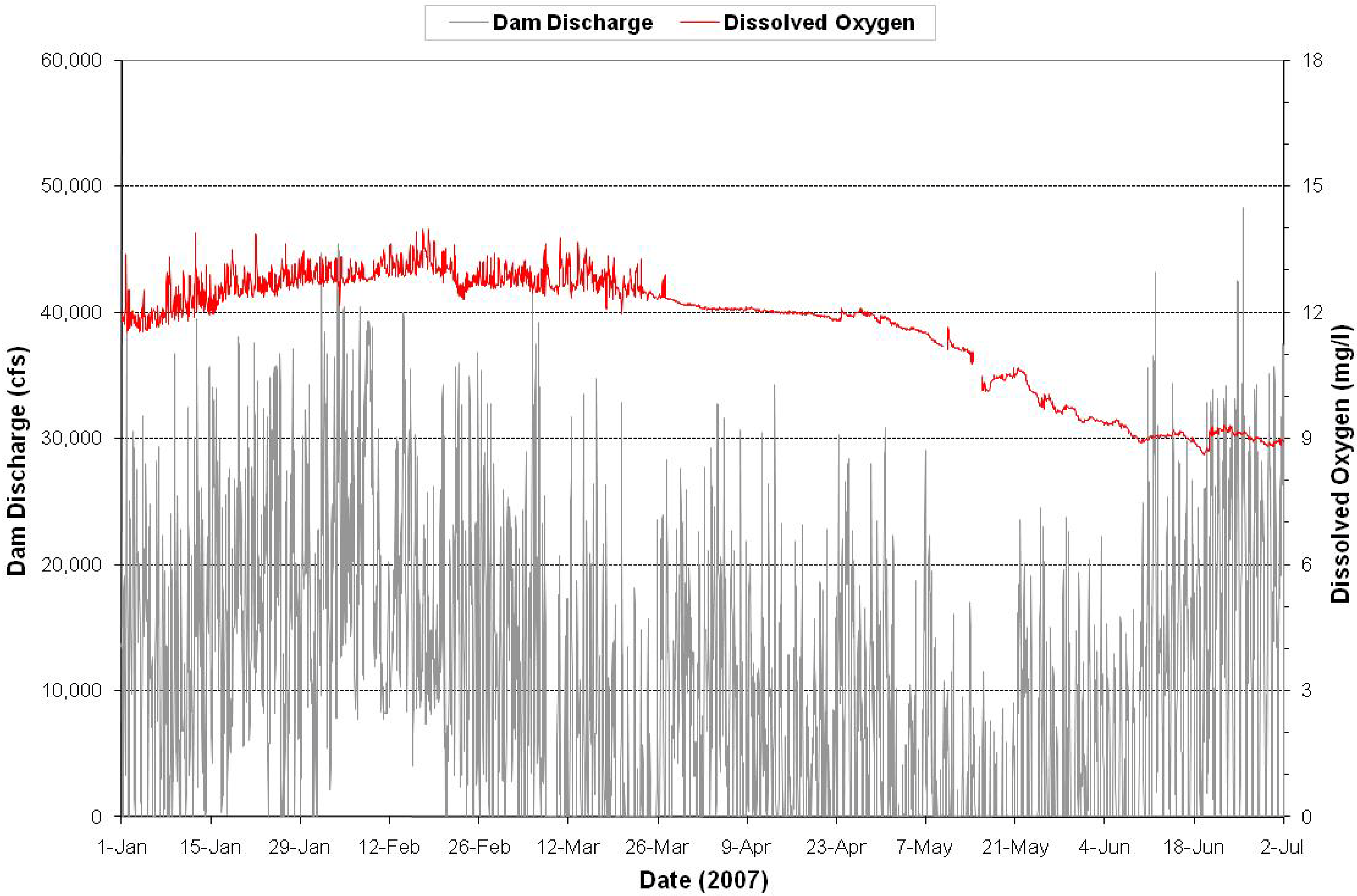

Plate 214. Hourly discharge and dissolved oxygen monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2007.

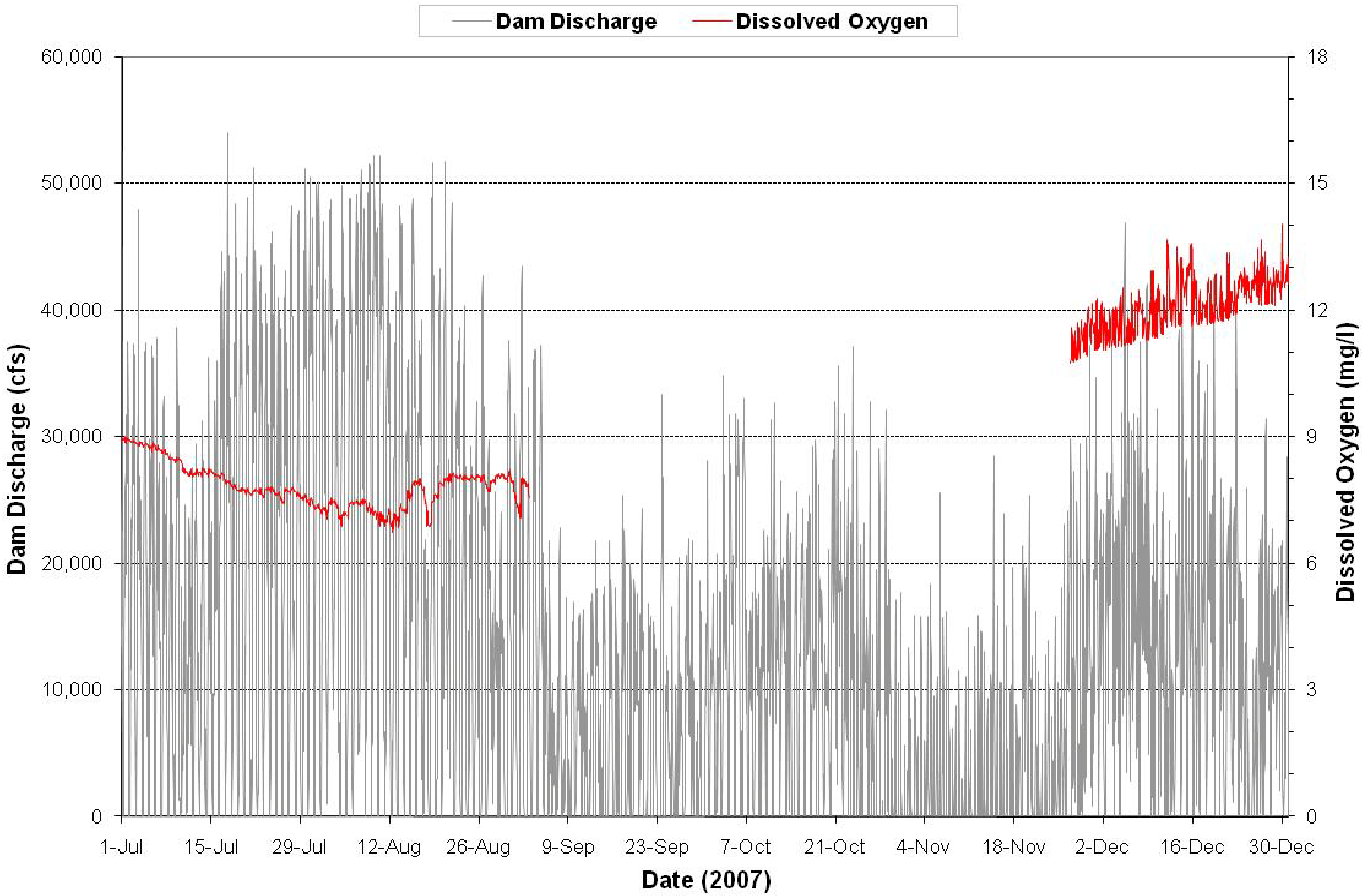

Plate 215. Hourly discharge and dissolved oxygen monitored at the Oahe Powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

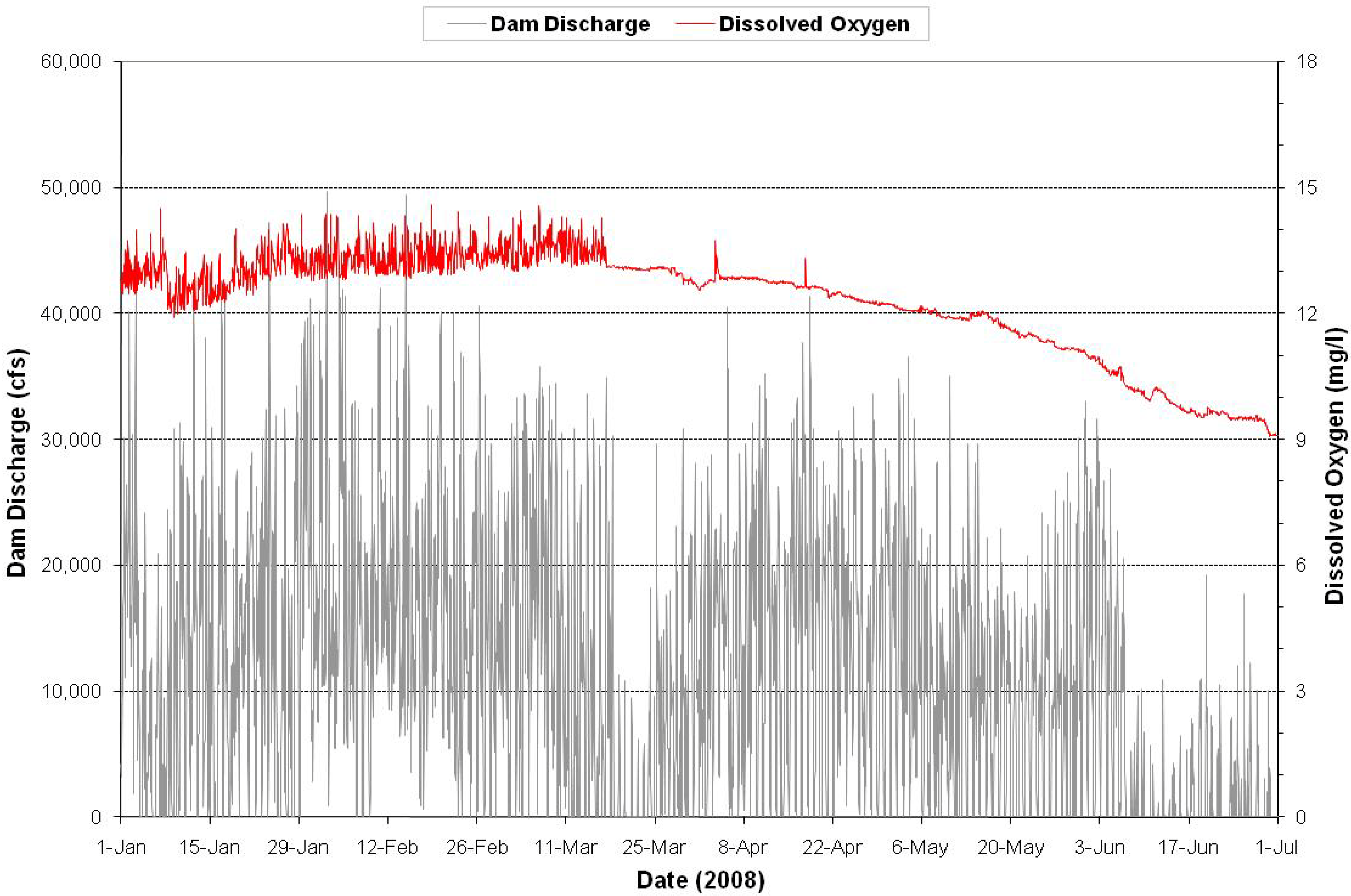

Plate 216. Hourly discharge and dissolved oxygen monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2008.

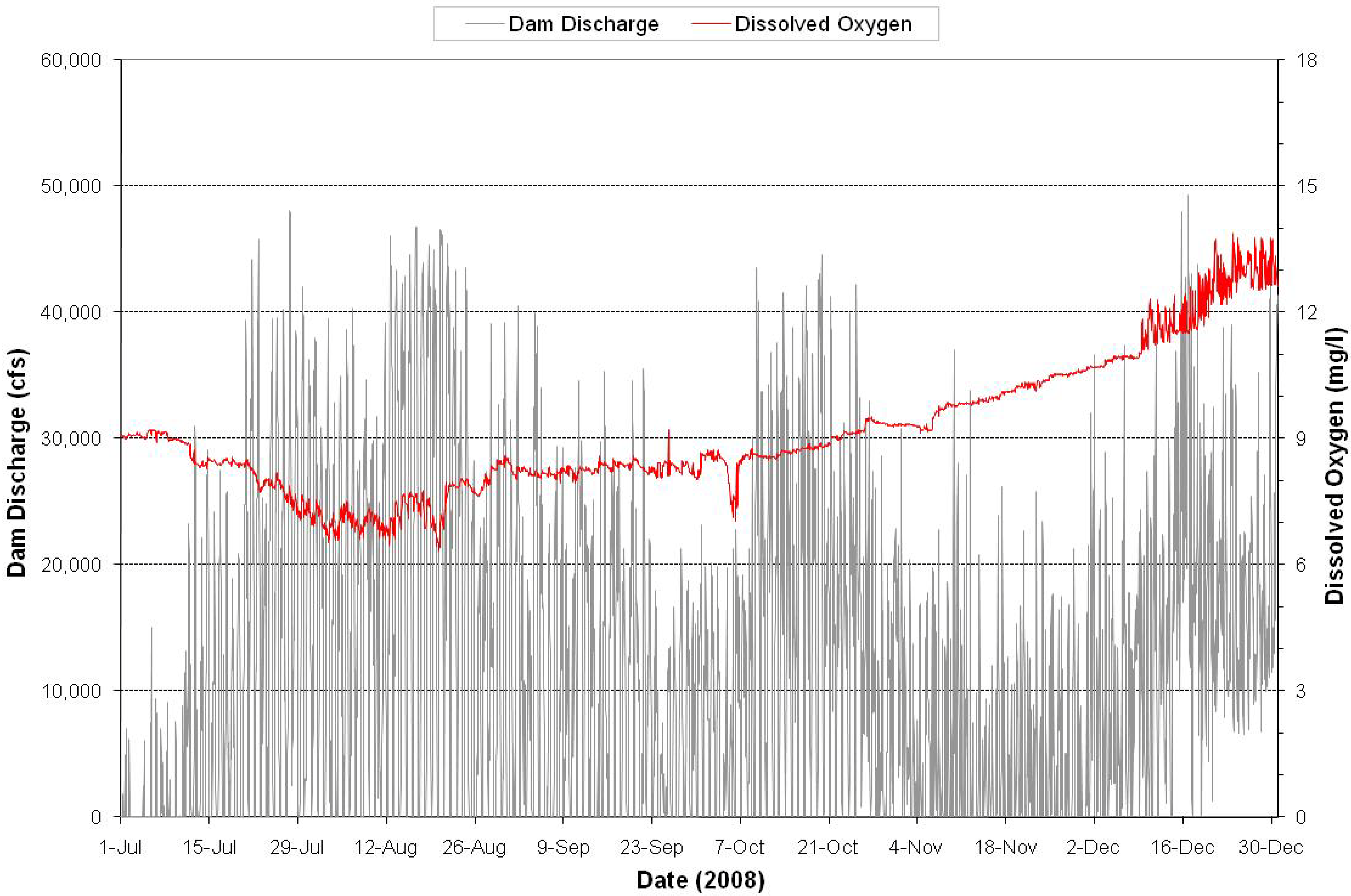

Plate 217. Hourly discharge and dissolved oxygen monitored at the Oahe Powerplant on water discharged through the dam during the period July through December 2008.

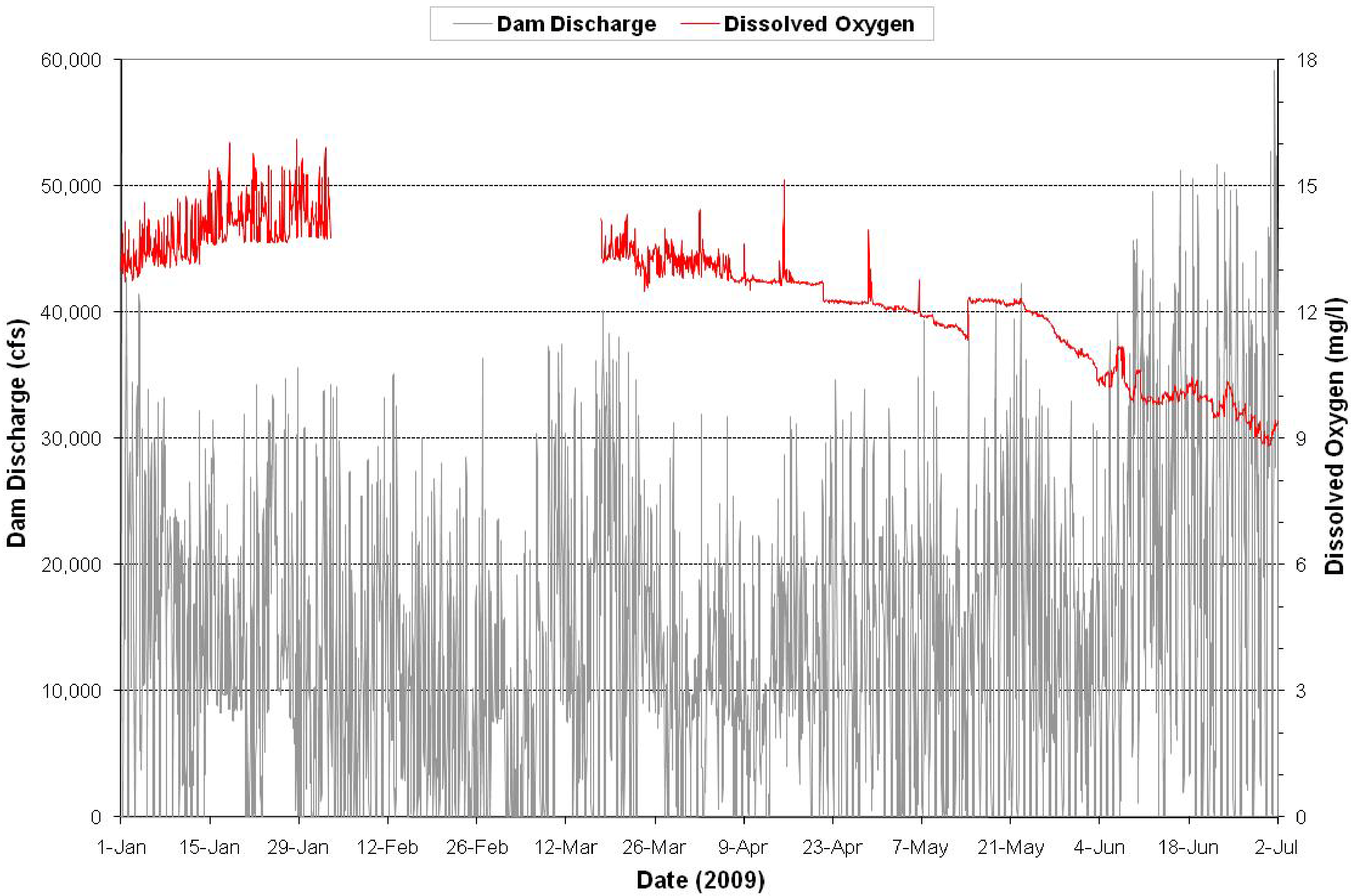

Plate 218. Hourly discharge and dissolved oxygen monitored at the Oahe Powerplant on water discharged through the dam during the period January through June 2009.

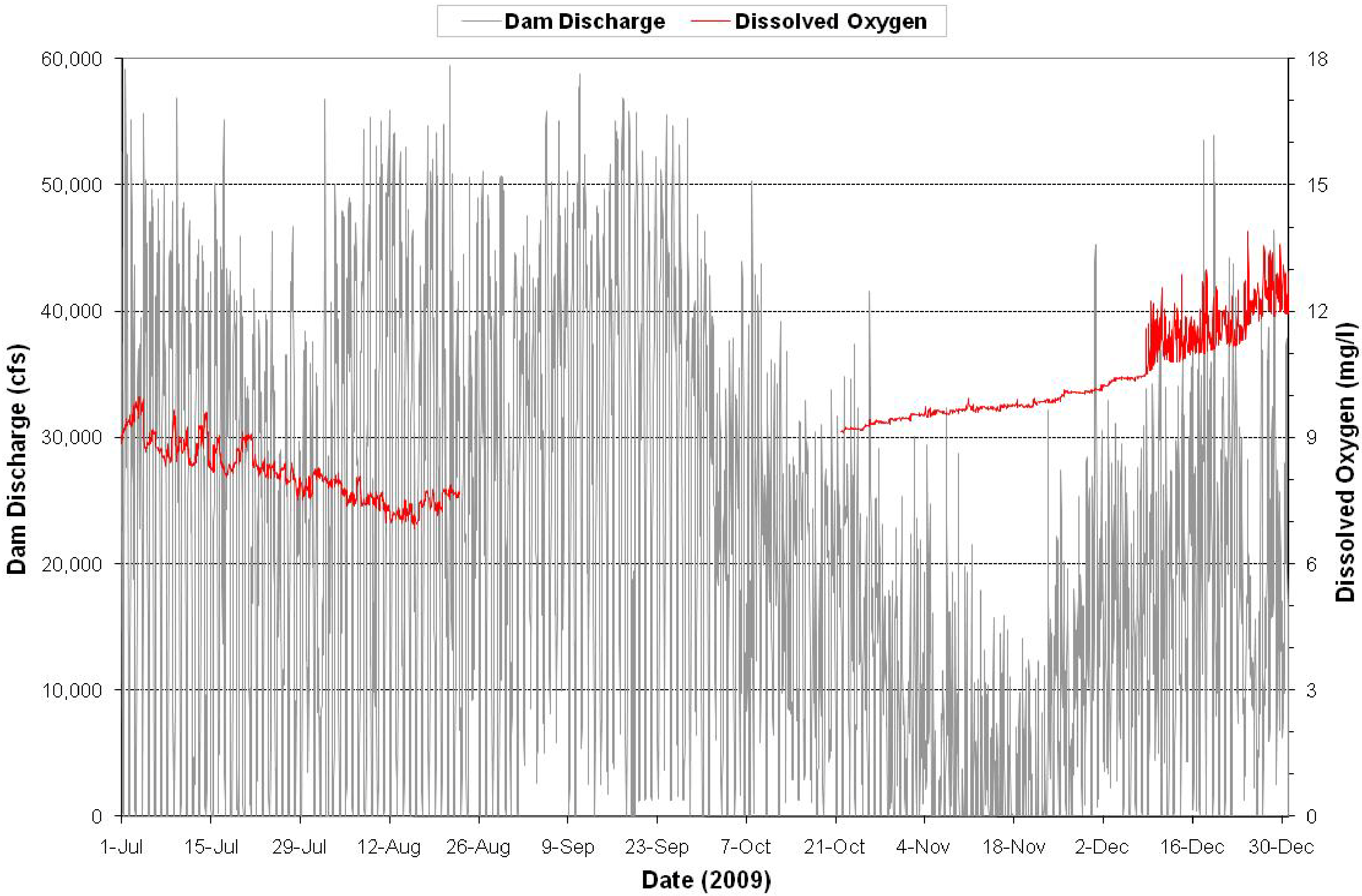

Plate 219. Hourly discharge and dissolved oxygen monitored at the Oahe Powerplant on water discharged through the dam during the period July through December 2009.

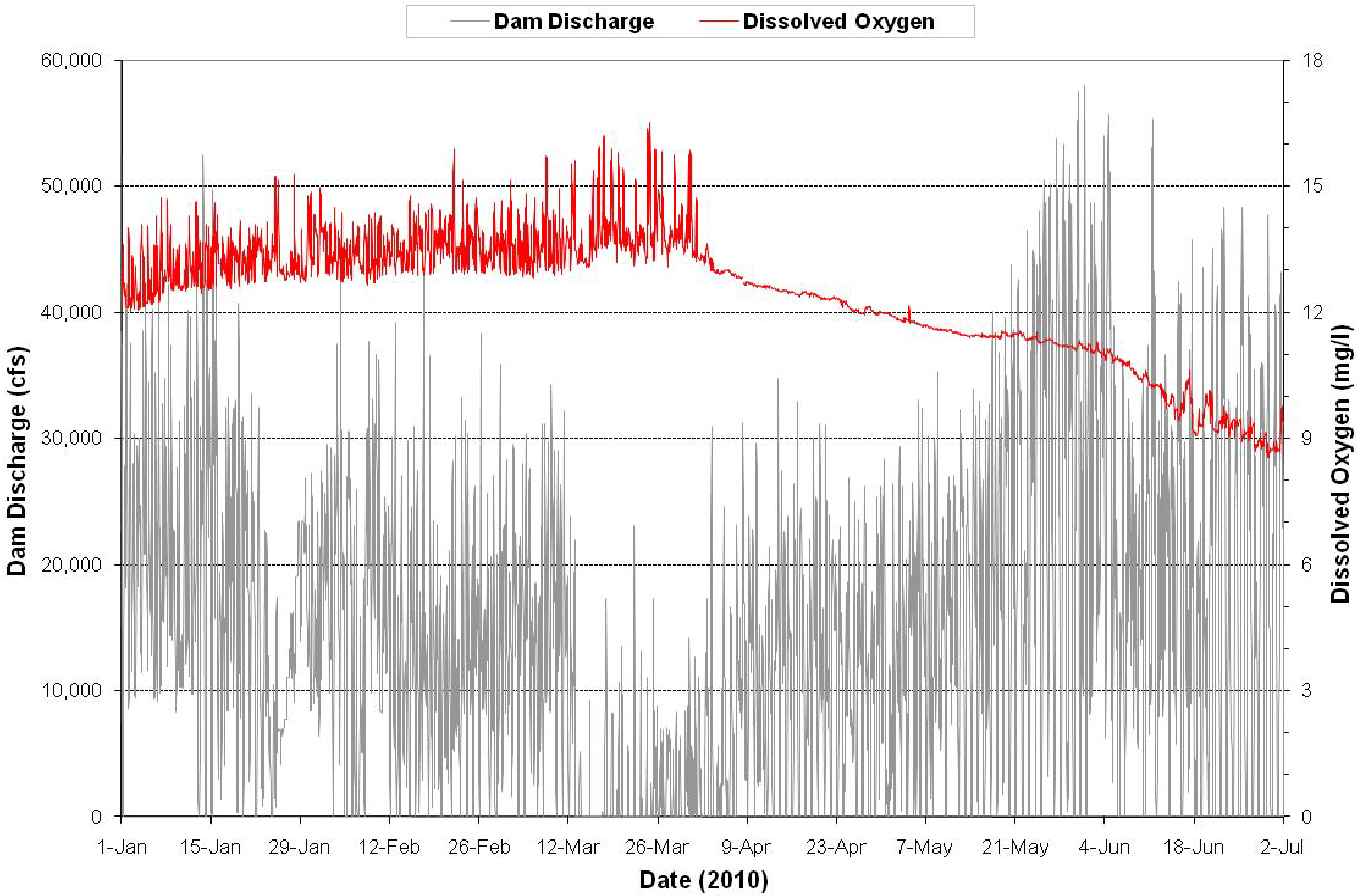

Plate 220. Hourly discharge and dissolved oxygen monitored at the Oahe Powerplant on water discharged through the dam during the period January through June 2010.

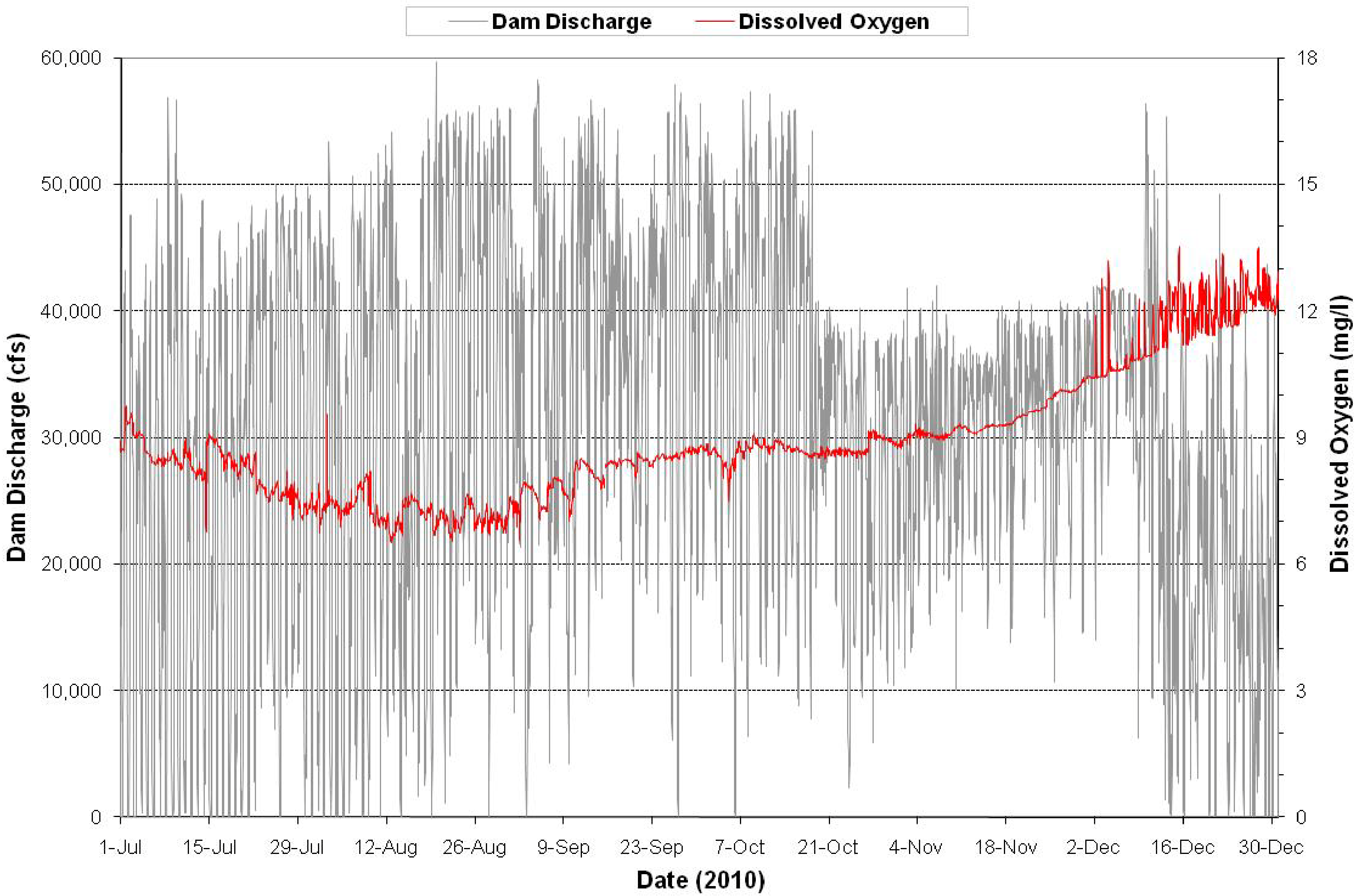

Plate 221. Hourly discharge and dissolved oxygen monitored at the Oahe Powerplant on water discharged through the dam during the period July through December 2010.

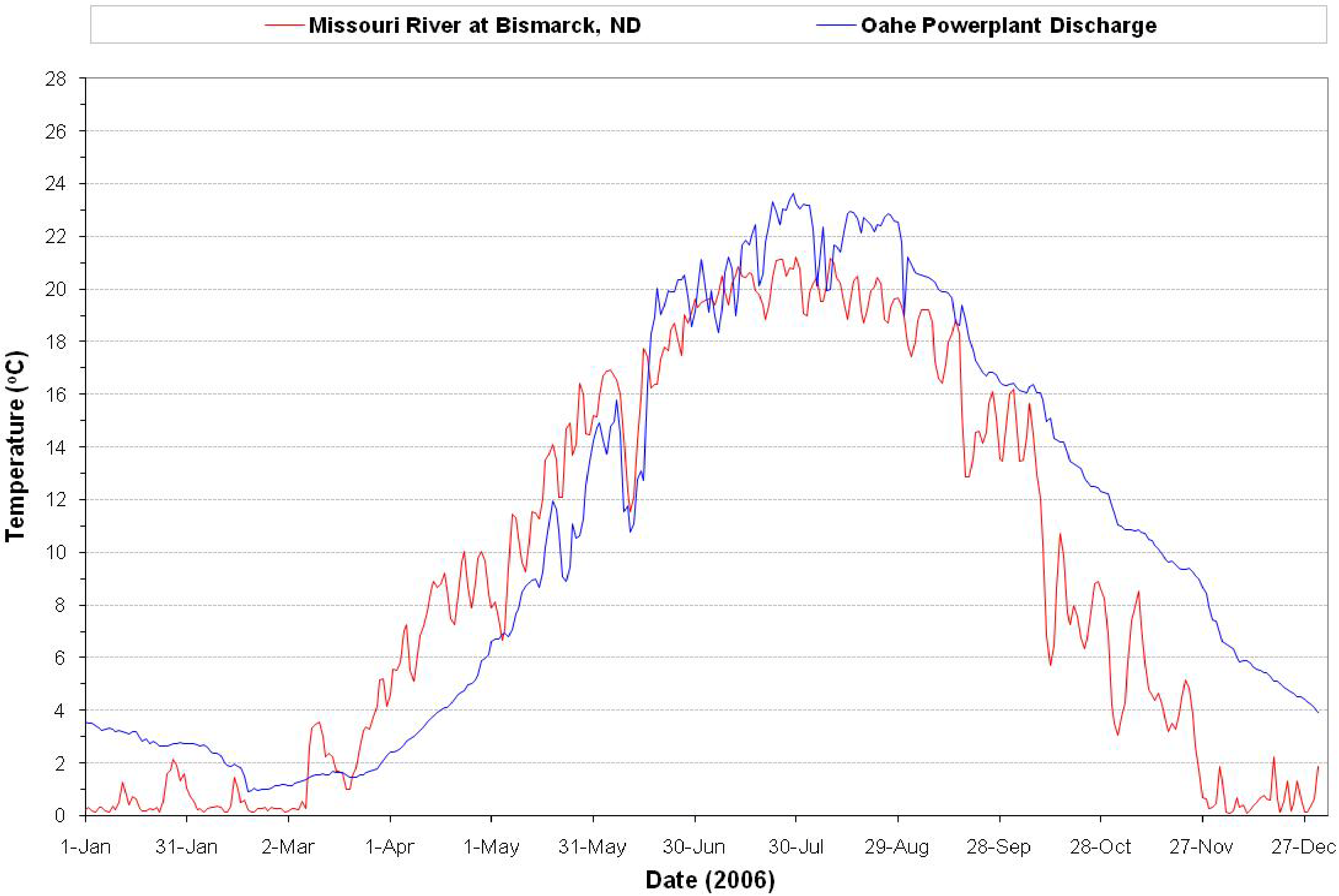

Plate 222. Mean daily water temperatures monitored at the Oahe Powerplant (i.e., site OAHPP1) and the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) during 2006.

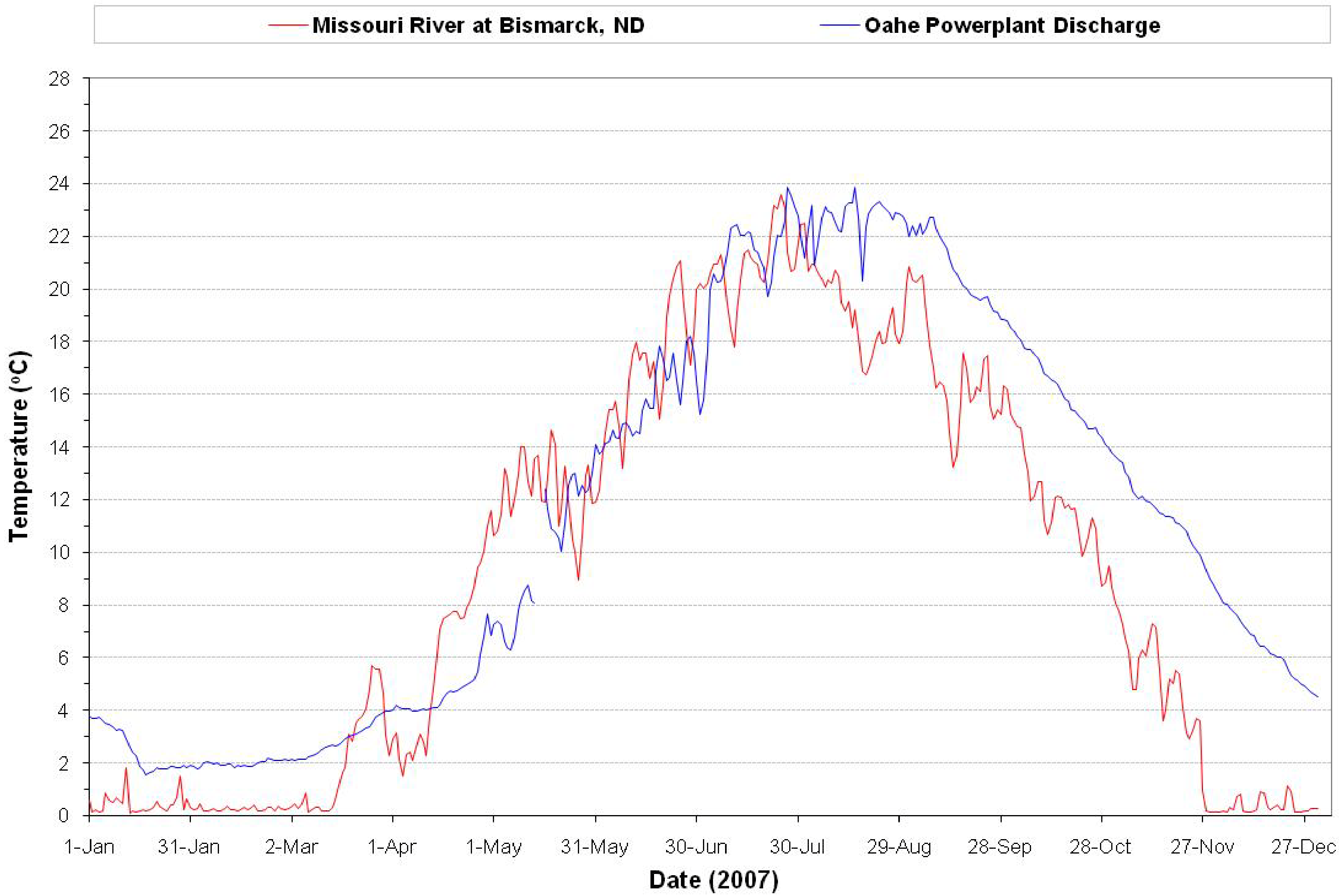

Plate 223. Mean daily water temperatures monitored at the Oahe Powerplant (i.e., site OAHPP1) and the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) during 2007.

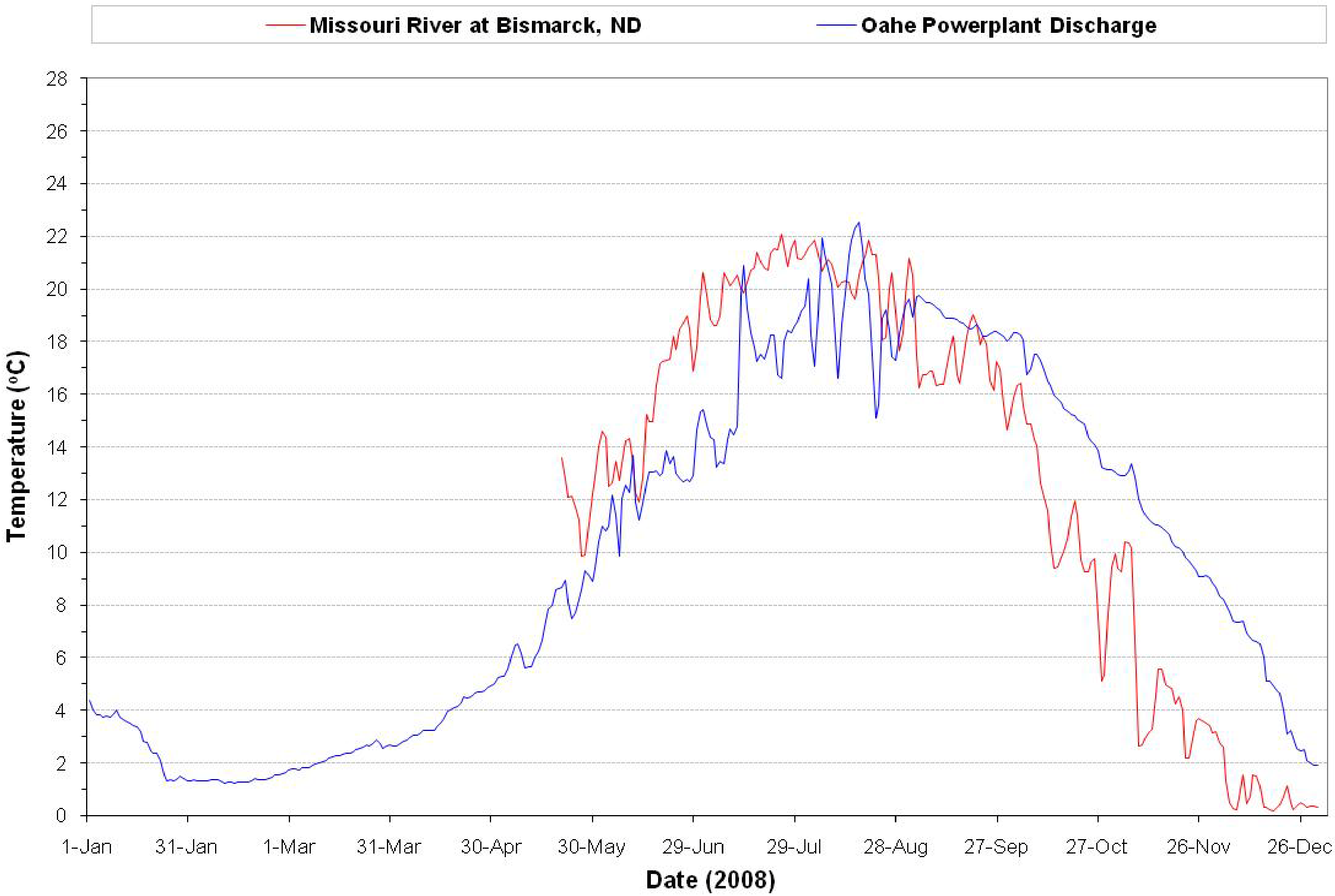

Plate 224. Mean daily water temperatures monitored at the Oahe Powerplant (i.e., site OAHPP1) and the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) during 2008.

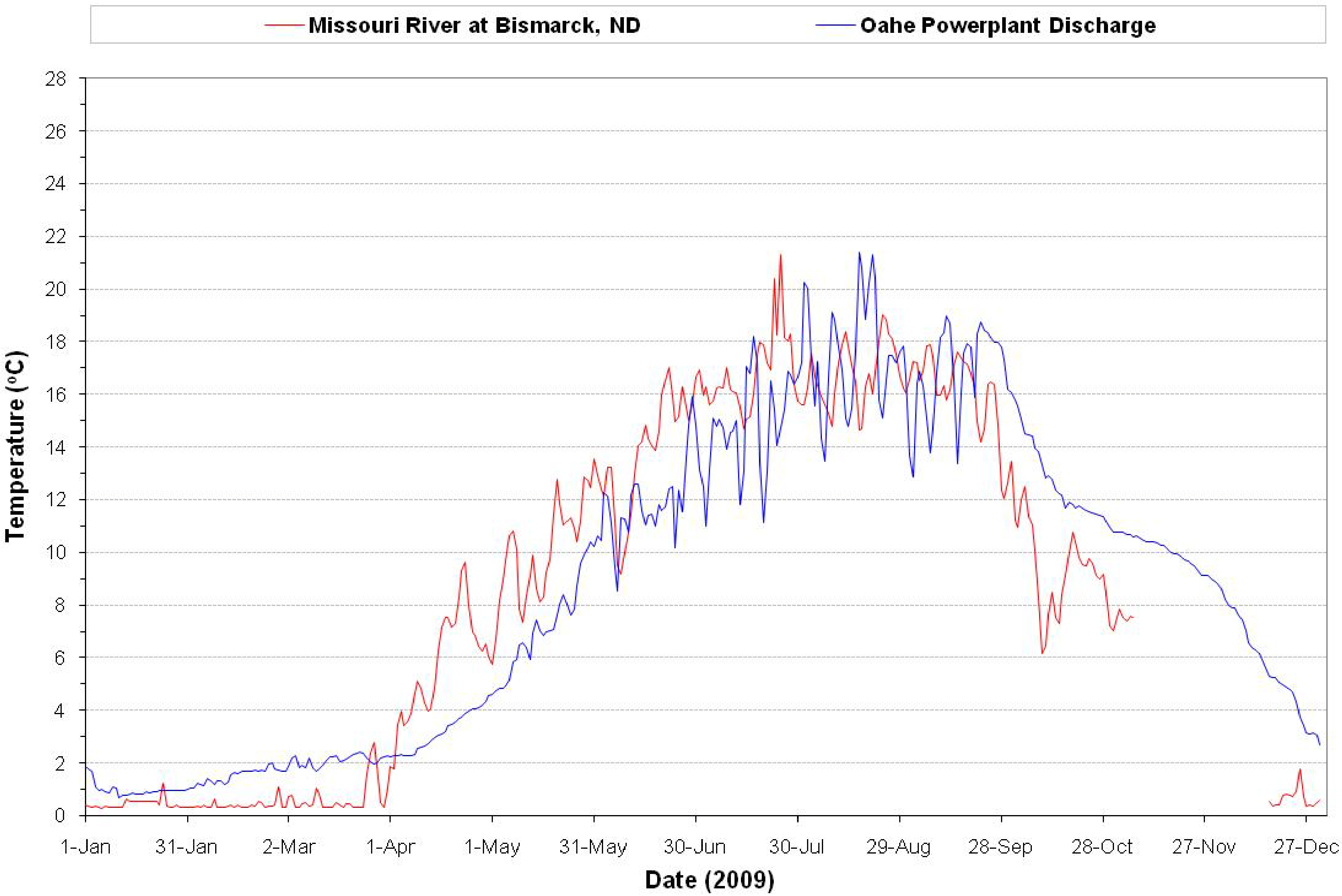

Plate 225. Mean daily water temperatures monitored at the Oahe Powerplant (i.e., site OAHPP1) and the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) during 2009.

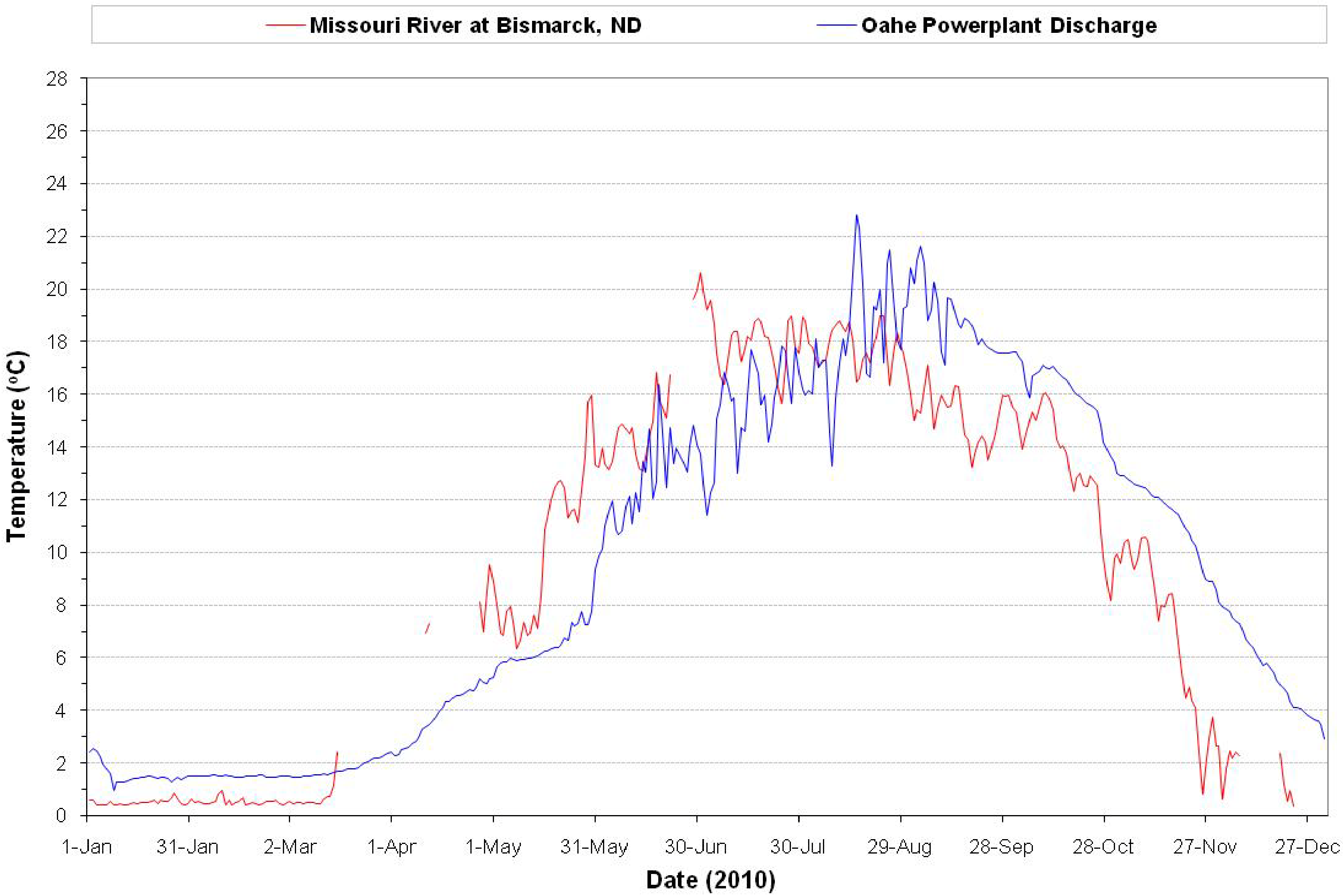

Plate 226. Mean daily water temperatures monitored at the Oahe Powerplant (i.e., site OAHPP1) and the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) during 2010.

Plate 227. Summary of monthly (May through September) water quality conditions monitored in Lake Sharpe near Big Bend Dam (Site BBDLK0987A) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	25	1420.3	1420.3	1419.9	1420.8	-----	-----	-----
Water Temperature (°C)	0.1	556	19.3	19.9	9.7	27.6	18.3[1,5]	359	65%
Hypolimnion Water Temperature (°C)[E]	0.1	22	21.8	22.7	18.5	24.3	18.3[1,5]	22	100%
Dissolved Oxygen (mg/l)	0.1	556	8.3	8.2	3.2	10.8	6[1,6,8], 7[1,6,8]	32, 67	6%, 12%
Dissolved Oxygen (% Sat.)	0.1	556	92.3	94.9	37.2	126.5	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	533	8.4	8.3	5.4	10.8	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	22	4.9	5.1	3.2	6.4	6[1,6,8]	20	91%
Specific Conductance (umhos/cm)	1	555	715	718	631	783	-----	-----	-----
pH (S.U.)	0.1	533	8.4	8.4	7.5	8.9	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	553	4	3	n.d.	38	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	488	330	330	198	441	-----	-----	-----
Secchi Depth (in.)	1	24	89	74	30	228	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	153	157	114	180	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	46	3.3	3.2	1.5	5.2	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	48	11	10	n.d.	20	-----	-----	-----
Chloride (mg/l)	1	38	11	11	9	14	175[1,5], 100[1,7], 438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	389	11	5	1	73	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	24	6	4	n.d.	26	-----	-----	-----
Color, True (APHA)	1	21	7	6	4	19	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	48	487	475	370	624	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	48	-----	0.02	n.d.	0.19	2.6[1,5,9], 0.86[1,7,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	48	-----	0.4	n.d.	1.0	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	48	-----	n.d.	n.d.	1.00	10[2,5]	0	0%
Nitrogen, Total (mg/l)	0.1	48	0.4	0.4	n.d.	1.6	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	48	-----	n.d.	n.d.	0.18	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	48	0.04	0.03	n.d.	0.24	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	48	-----	n.d.	n.d.	0.16	-----	-----	-----
Sulfate (mg/l)	1	48	206	210	165	238	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	48	-----	n.d.	n.d.	11	53[1,5], 30[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	23	-----	n.d.	n.d.	0.3	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	25	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	15	60%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of 1.0°C or at least 0.5°C occurs over a 1-meter depth increment. A defined hypolimnion was monitored on 4 of the 25 occasions (i.e., 16%) that monthly depth profiles were measured from May through September. Measured water depths in this area of Lake Sharpe were < 23 meters.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile. During the 5-year period 2006 through 2010, water temperatures greater than 18.3°C throughout the water column precluded the occurrence of Coldwater Permanent Fish Life Propagation habitat from late-June through early-September.

Plate 228. Summary of monthly (June through September) water quality conditions monitored at Lake Sharpe in the North Bend area (site BBDLK1004DW) during the 2-year period 2008 through 2009.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	7	1420.3	1420.4	1419.7	1420.8	-----	-----	-----
Water Temperature (°C)	0.1	126	21.0	21.1	14.5	26.8	18.3[1,5]	108	86%
Hypolimnion Water Temperature (°C)[E]	0.1	14	21.1	21.3	19.0	22.8	18.3[1,5]	14	100%
Dissolved Oxygen (mg/l)	0.1	126	8.2	8.4	5.2	9.7	6[1,6,8], 7[1,6,8]	2, 22	2%, 17%
Dissolved Oxygen (% Sat.)	0.1	126	94.9	97.7	65.3	113.5	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	112	8.2	8.4	5.2	9.7	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	14	7.8	7.8	6.1	9.7	6[1,6,8]	0	0%
Specific Conductance (umhos/cm)	1	126	728	727	704	756	-----	-----	-----
pH (S.U.)	0.1	126	8.4	8.3	7.8	8.9	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	126	4	4	n.d.	16	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	108	333	319	254	462	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	123	10	7	2	27	-----	-----	-----
Secchi Depth (in)	1	7	74	67	48	146	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[f]	-----	7	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	6	86%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment. A defined hypolimnion was monitored on 1 of the 7 occasions (i.e., 14%) that monthly depth profiles were measured from June through September. Measured water depths in this area of Lake Sharpe were < 18 meters.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile. During the 2-year period 2008 through 2009, water temperatures greater than 18.3°C throughout the water column precluded the occurrence of Coldwater Permanent Fish Life Propagation habitat from late-June through mid-September.

Plate 229. Summary of monthly (May through September) water quality conditions monitored in Lake Sharpe in the Iron Nation area (Site BBDLK1020DW) during the 3-year period 2008 through 2010.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	12	1420.3	1420.3	1419.8	1420.9	-----	-----	-----
Water Temperature (°C)	0.1	148	20.3	20.0	15.1	27.3	18.3[1,5]	112	76%
Hypolimnion Water Temperature (°C)[E]	0.1	0	-----	-----	-----	-----	18.3[1,5]	-----	-----
Dissolved Oxygen (mg/l)	0.1	148	8.8	8.9	6.4	10.5	6[1,6,8], 7[1,6,8]	0, 6	0%, 4%
Dissolved Oxygen (% Sat.)	0.1	148	101.0	98.9	75.9	133.9	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	148	8.8	8.9	6.4	10.5	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0	-----	-----	-----	-----	6[1,6,8]	0	0%
Specific Conductance (umhos/cm)	1	148	722	723	683	770	-----	-----	-----
pH (S.U.)	0.1	148	8.4	8.4	7.8	9.0	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	147	8	8	2	22	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	136	323	338	205	408	-----	-----	-----
Secchi Depth (in.)	1	12	42	36	24	96	-----	-----	-----
Alkalinity, Total (mg/l)	7	24	152	153	133	165	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	24	3.6	3.6	2.4	5.0	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	24	12	12	7	18	-----	-----	-----
Chloride (mg/l)	1	16	12	12	11	13	175[1,5], 100[1,7], 438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	146	9	8	3	30	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	12	8	9	4	13	-----	-----	-----
Color, True (APHA)	1	8	7	6	4	13	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	24	507	487	386	726	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	24	-----	n.d.	n.d.	0.20	2.6 [1,5,9], 0.86 [1,7,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	24	0.7	0.5	0.2	2.6	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	24	-----	n.d.	n.d.	0.23	10[2,5]	0	0%
Nitrogen, Total (mg/l)	0.1	24	0.8	0.6	0.2	2.6	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	24	-----	0.02	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	24	0.04	0.04	n.d.	0.21	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	24	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	24	206	208	182	222	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	24	-----	6	n.d.	32	53[1,5], 30[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	12	-----	n.d.	n.d.	0.4	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	12	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	8	67%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of 1.0°C or at least 0.5°C occurs over a 1-meter depth increment. A defined hypolimnion was monitored on 1 of the 8 occasions (i.e., 13%) that monthly depth profiles were measured from June through September. Measured water depths in this area of Lake Sharpe were < 12.5 meters.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile. During the 3-year period 2008 through 2010, water temperatures greater than 18.3°C throughout the water column precluded the occurrence of Coldwater Permanent Fish Life Propagation habitat from late-June through early-September.

Plate 230. Summary of monthly (June through September) water quality conditions monitored at Lake Sharpe in the Cedar Creek area (site BBDLK1036DW) during the 2-year period 2008 through 2009.

Parameter	Monitoring Results(A)						Water Quality Standards Attainment		
	Detection Limit(B)	No. of Obs.	Mean(C)	Median	Min.	Max.	State WQS Criteria(D)	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	7	1420.4	1420.4	1420.0	1420.9	-----	-----	-----
Water Temperature (°C)	0.1	43	19.6	18.1	16.7	24.3	18.3(1,5)	12	50%
Hypolimnion Water Temperature (°C)(E)	0.1	0	-----	-----	-----	-----	18.3(1,5)	-----	-----
Dissolved Oxygen (mg/l)	0.1	43	8.6	8.7	7.6	9.2	6(1,6,8), 7(1,6,8)	0	0%
Dissolved Oxygen (% Sat.)	0.1	43	96.8	96.0	91.6	104.9	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)(E)	0.1	43	8.6	8.7	7.6	9.2	5(3,6)	0	0%
Hypolimnion Dissolved Oxygen (mg/l)(E)	0.1	0	-----	-----	-----	-----	6(1,6,8)	-----	-----
Specific Conductance (umhos/cm)	1	43	760	723	712	908	-----	-----	-----
pH (S.U.)	0.1	43	8.4	8.3	8.0	9.0	6.5(1,2,6), 9.0(1,2,5), 9.5(4,5)	0	0%
Turbidity (NTUs)	1	43	30	27	12	65	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	43	351	319	268	469	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	43	10	10	4	16	-----	-----	-----
Secchi Depth (in)	1	7	13	13	8	20	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat(F)	-----	7	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	3	43%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of 1.0°C or at least 0.5°C occurs over a 1-meter depth increment. A defined hypolimnion was not monitored on any of the 7 occasions that monthly depth profiles were measured from June through September. This is attributed to the shallower water depths (<6.5 meters) in this area of Lake Sharpe.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile. During the 2-year period 2008 through 2009, water temperatures greater than 18.3°C throughout the water column precluded the occurrence of Coldwater Permanent Fish Life Propagation habitat in July and August 2008, and August 2009.

Plate 231. Summary of monthly (May through September) water quality conditions monitored in Lake Sharpe in the Antelope Creek area (Site BBDLK1055DW) during the 3-year period 2008 through 2010.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	13	1420.3	1420.4	1419.9	1420.8	-----	-----	-----
Water Temperature (°C)	0.1	46	18.4	18.6	12.9	22.8	18.3[1,5]	25	54%
Hypolimnion Water Temperature (°C)[E]	0.1	0	-----	-----	-----	-----	18.3[1,5]	-----	-----
Dissolved Oxygen (mg/l)	0.1	46	8.7	8.5	7.6	10.2	6[1,6,8], 7[1,6,8]	0	0%
Dissolved Oxygen (% Sat.)	0.1	46	95.6	93.6	79.7	109.7	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	46	8.7	8.5	7.6	10.2	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0	-----	-----	-----	-----	6[1,6,8]	-----	-----
Specific Conductance (umhos/cm)	1	46	745	715	689	1,454	-----	-----	-----
pH (S.U.)	0.1	46	8.3	8.3	7.9	8.9	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	46	56	45	7	188	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	46	343	319	210	474	-----	-----	-----
Secchi Depth (in.)	1	12	12	8	6	26	-----	-----	-----
Alkalinity, Total (mg/l)	7	13	152	151	122	179	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	13	4.2	4.0	2.6	9.1	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	13	12	11	4	28	-----	-----	-----
Chloride (mg/l)	1	8	12	12	10	16	175[1,5], 100[1,7], 438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	44	6	6	2	12	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	13	6	6	2	11	-----	-----	-----
Color, True (APHA)	1	5	9	6	5	20			
Dissolved Solids, Total (mg/l)	5	13	580	554	382	1,042	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0, 1, 0, 0	0%, 8%, 0%, 0%
Nitrogen, Ammonia Total (mg/l)	0.02	13	-----	0.03	n.d.	0.27	3.1 [1,5,9], 1.1 [1,7,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	13	1.2	0.5	n.d.	9.1	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	13	-----	0.05	n.d.	1.2	10[2,5]	0	0%
Nitrogen, Total (mg/l)	0.1	13	1.4	0.5	0.1	10.3	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	13	-----	0.02	n.d.	0.05	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	13	0.08	0.07	0.02	0.26	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	13	-----	0.02	n.d.	0.05	-----	-----	-----
Sulfate (mg/l)	1	13	233	207	190	509	875[2,5], 500[2,7]	0, 1	0%, 8%
Suspended Solids, Total (mg/l)	4	13	69	67	7	285	53[1,5], 30[1,7]	7, 9	54%, 69%
Microcystin, Total (ug/l)	0.2	12	-----	n.d.	n.d.	0.3	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	13	-----	-----	-----	-----	D.O ≥ 6 mg/l W. Temp. ≤ 18.3°C	5	38%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of 1.0°C or at least 0.5°C occurs over a 1-meter depth increment. A defined hypolimnion was not monitored on any of the 8 occasions that monthly depth profiles were measured from June through September. This is attributed to the shallower water depths (<5 meters) in this area of Lake Sharpe.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile. During the 5-year period 2006 through 2010, water temperatures greater than 18.3°C throughout the water column precluded the occurrence of Coldwater Permanent Fish Life Propagation habitat from late-June through early-September.

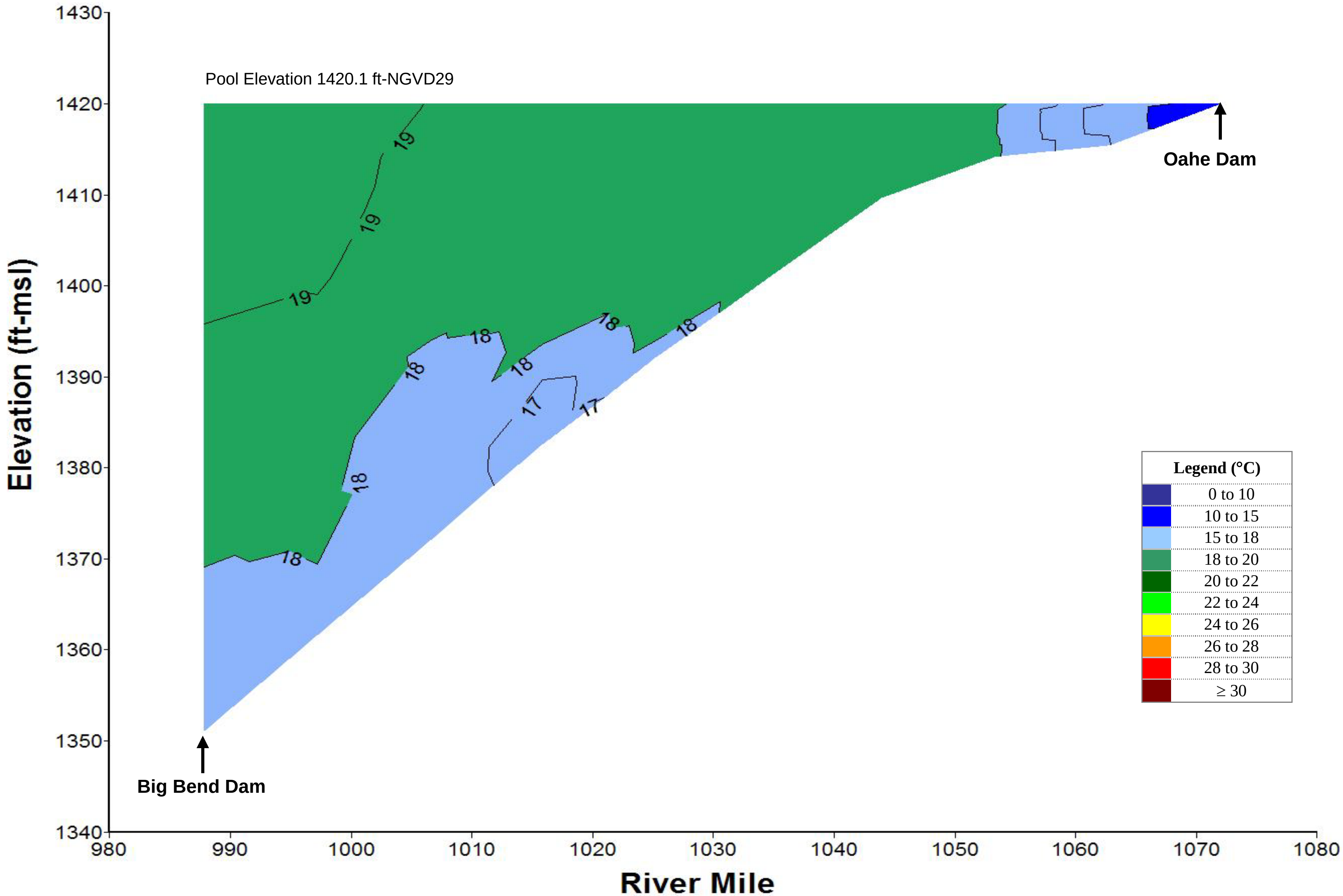

Plate 232. Longitudinal water temperature (°C) contour plot of Lake Sharpe based on depth-profile water temperatures measured at sites BBDLK0987A, BBDLK1020DW, BBDLK1055DW and OAHPP1 on June 16, 2010.

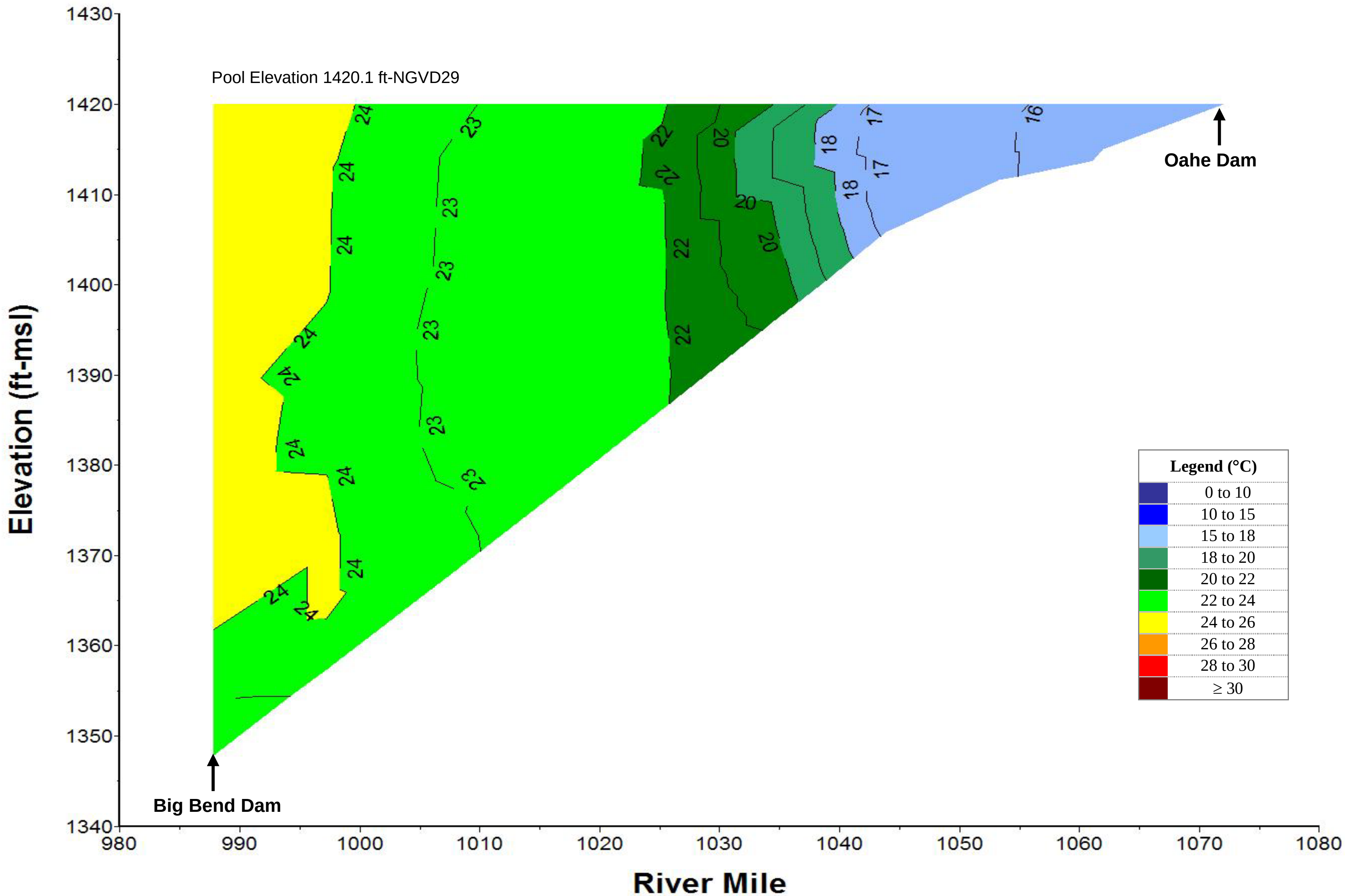

Plate 233. Longitudinal water temperature (°C) contour plot of Lake Sharpe based on depth-profile water temperatures measured at sites BBDLK0987A, BBDLK1020DW, BBDLK1055DW and OAHPP1 on July 14, 2010.

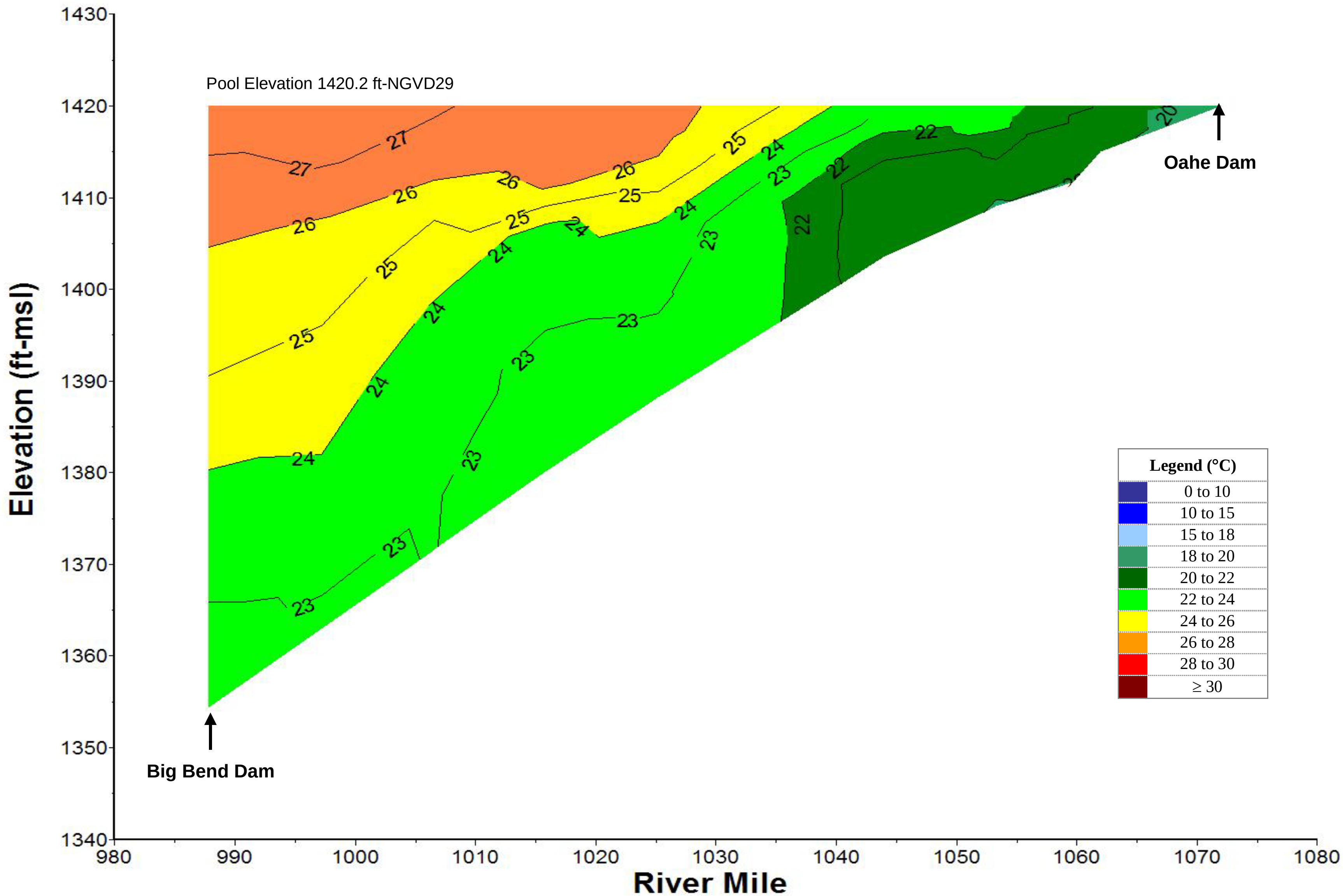

Plate 234. Longitudinal water temperature (°C) contour plot of Lake Sharpe based on depth-profile water temperatures measured at sites BBDLK0987A, BBDLK1020DW, BBDLK1055DW and OAHPP1 on August 11, 2010.

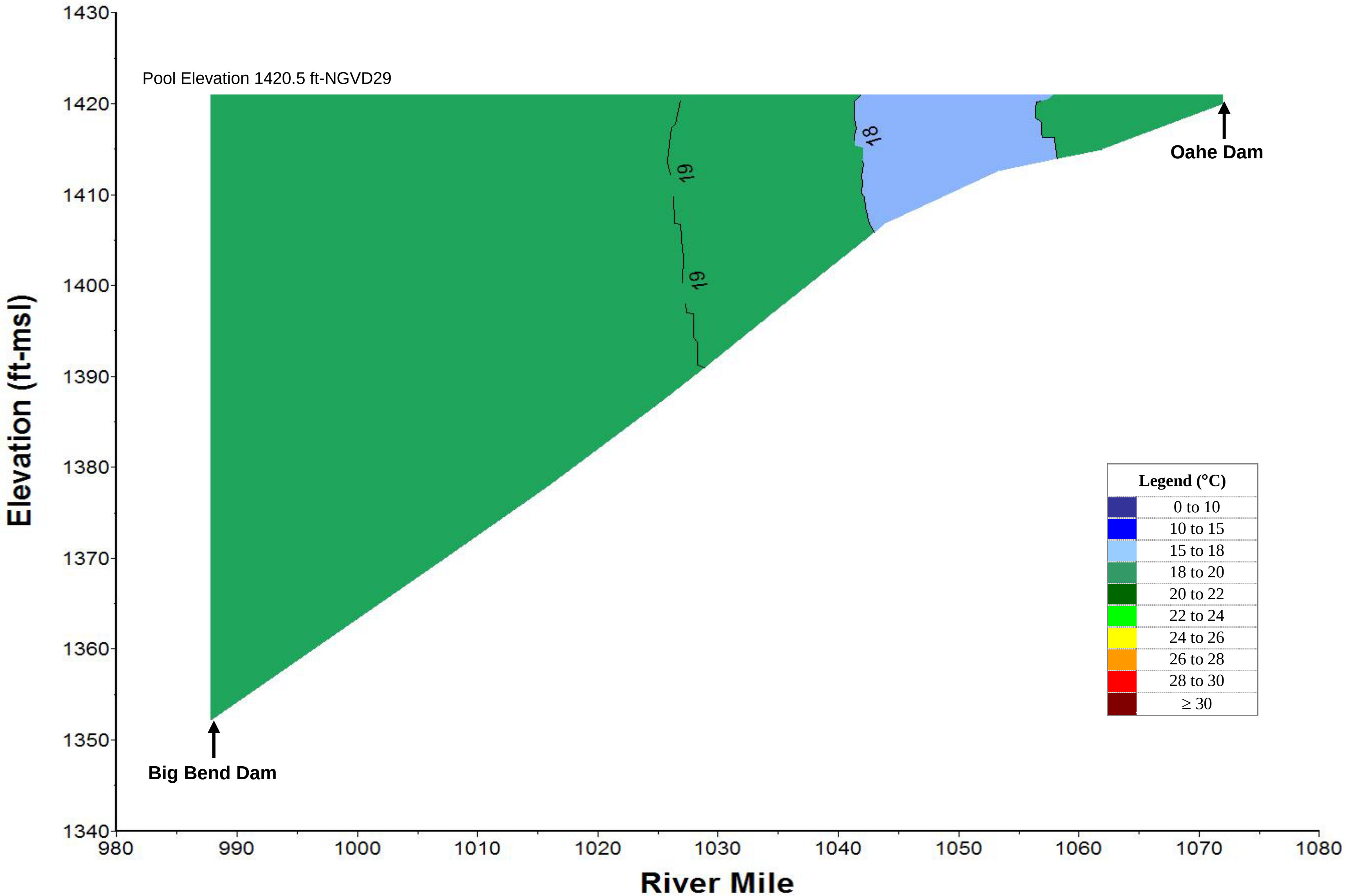

Plate 235. Longitudinal water temperature (°C) contour plot of Lake Sharpe based on depth-profile water temperatures measured at sites BBDLK0987A, BBDLK1020DW, BBDLK1055DW and OAHPP1 on September 16, 2010**.**

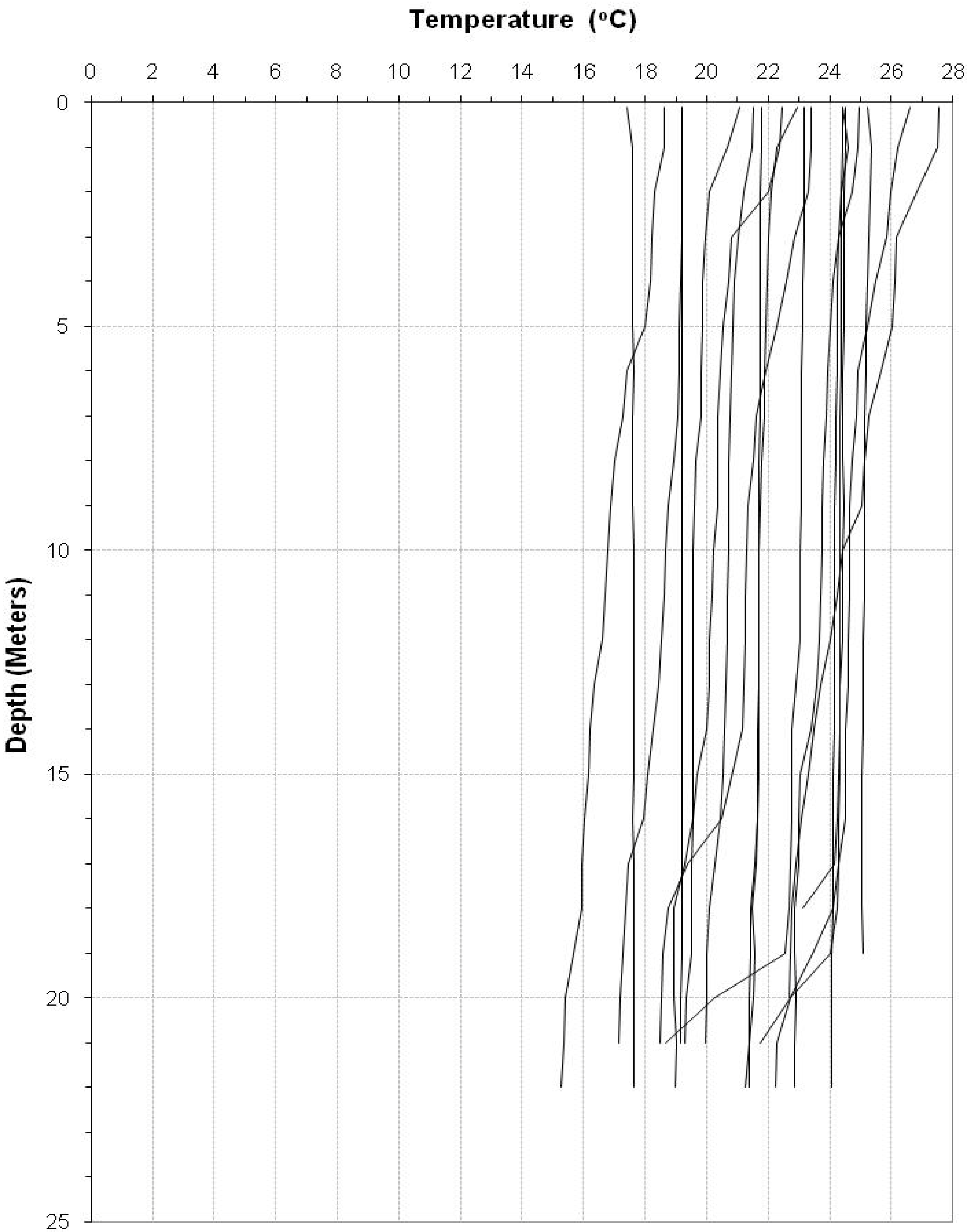

Plate 236. Temperature depth profiles for Lake Sharpe generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., BBDLK0987A) during the summer months of the 5-year period 2006 to 2010.

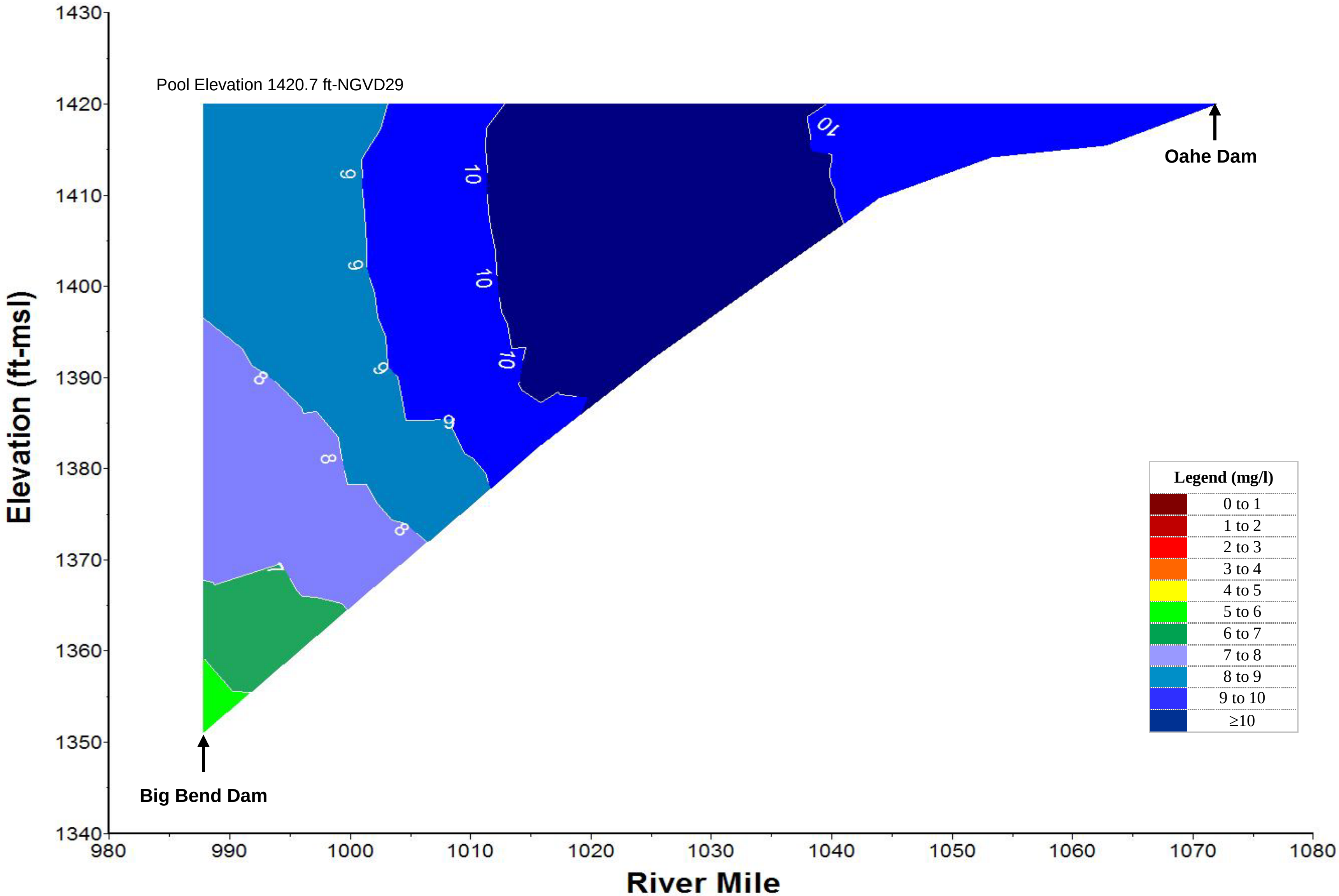

Plate 237. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Sharpe based on depth-profile dissolved oxygen concentrations measured at sites BBDLK0987A, BBDLK1020DW, BBDLK1055DW and OAHPP1 on June 16, 2010.

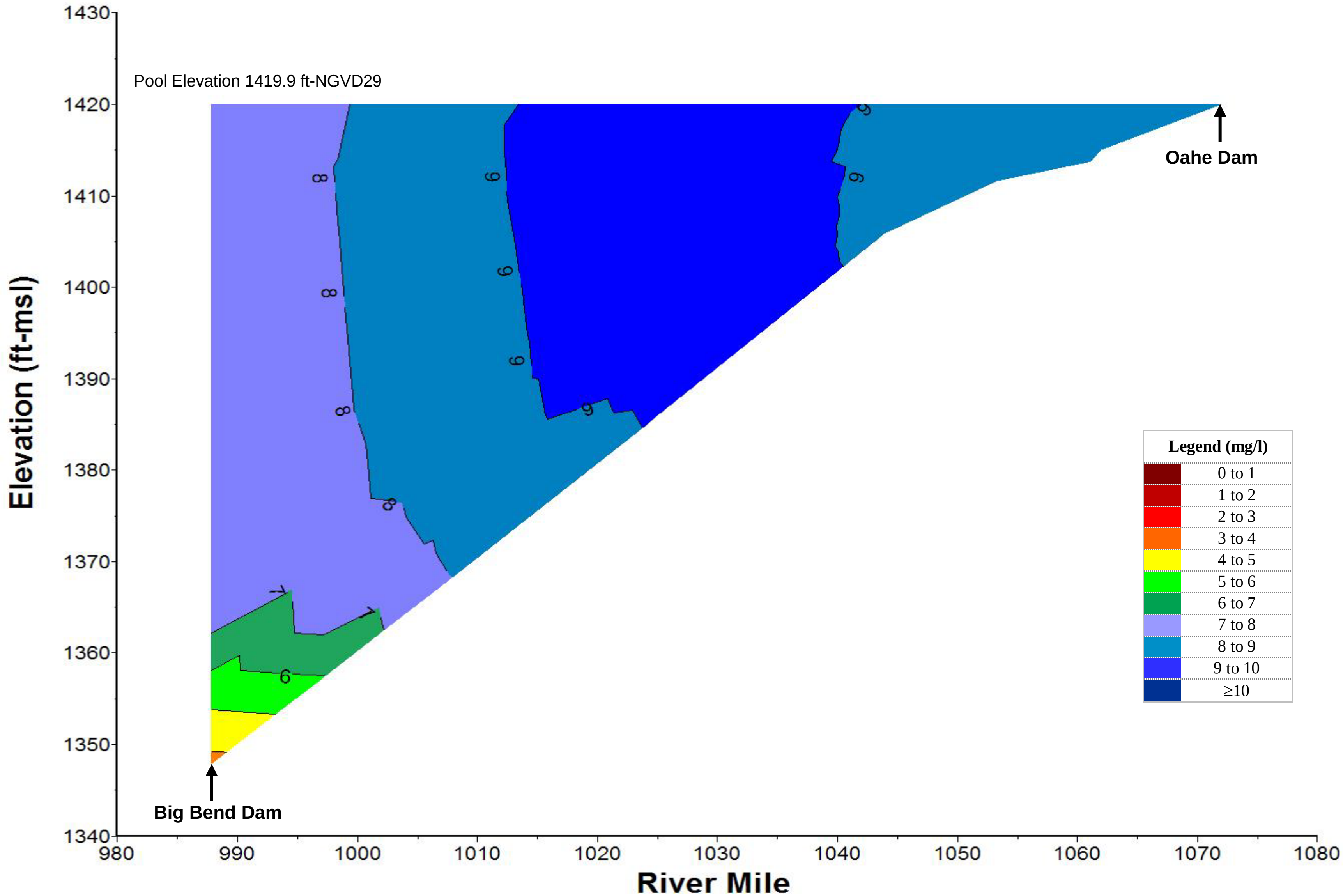

Plate 238. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Sharpe based on depth-profile dissolved oxygen concentrations measured at sites BBDLK0987A, BBDLK1020DW, BBDLK1055DW, and OAHPP1 on July 14, 2010.

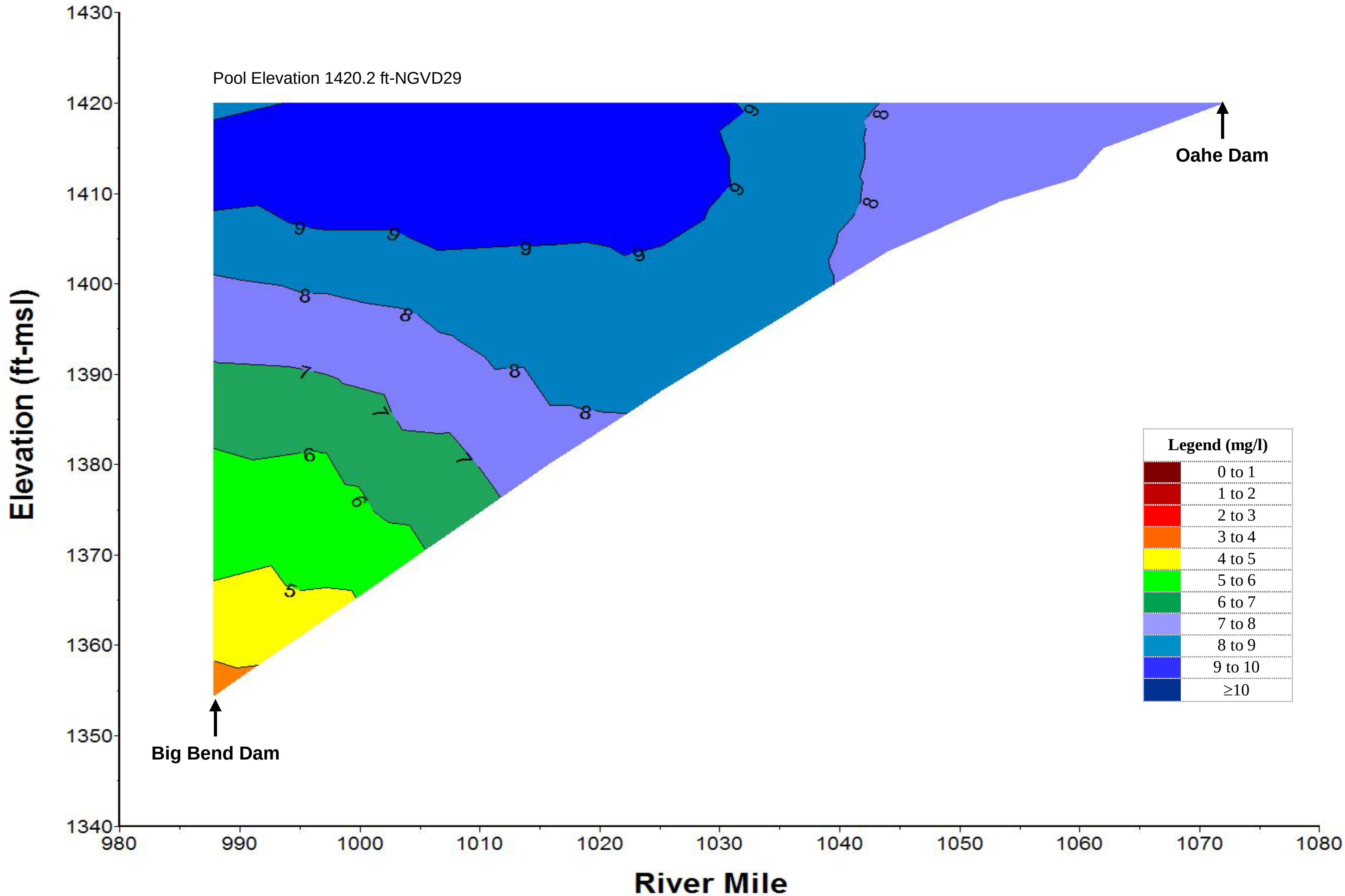

Plate 239. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Sharpe based on depth-profile dissolved oxygen concentrations measured at sites BBDLK0987A, BBDLK1020DW, BBDLK1055DW and OAHPP1 on August 11, 2010.

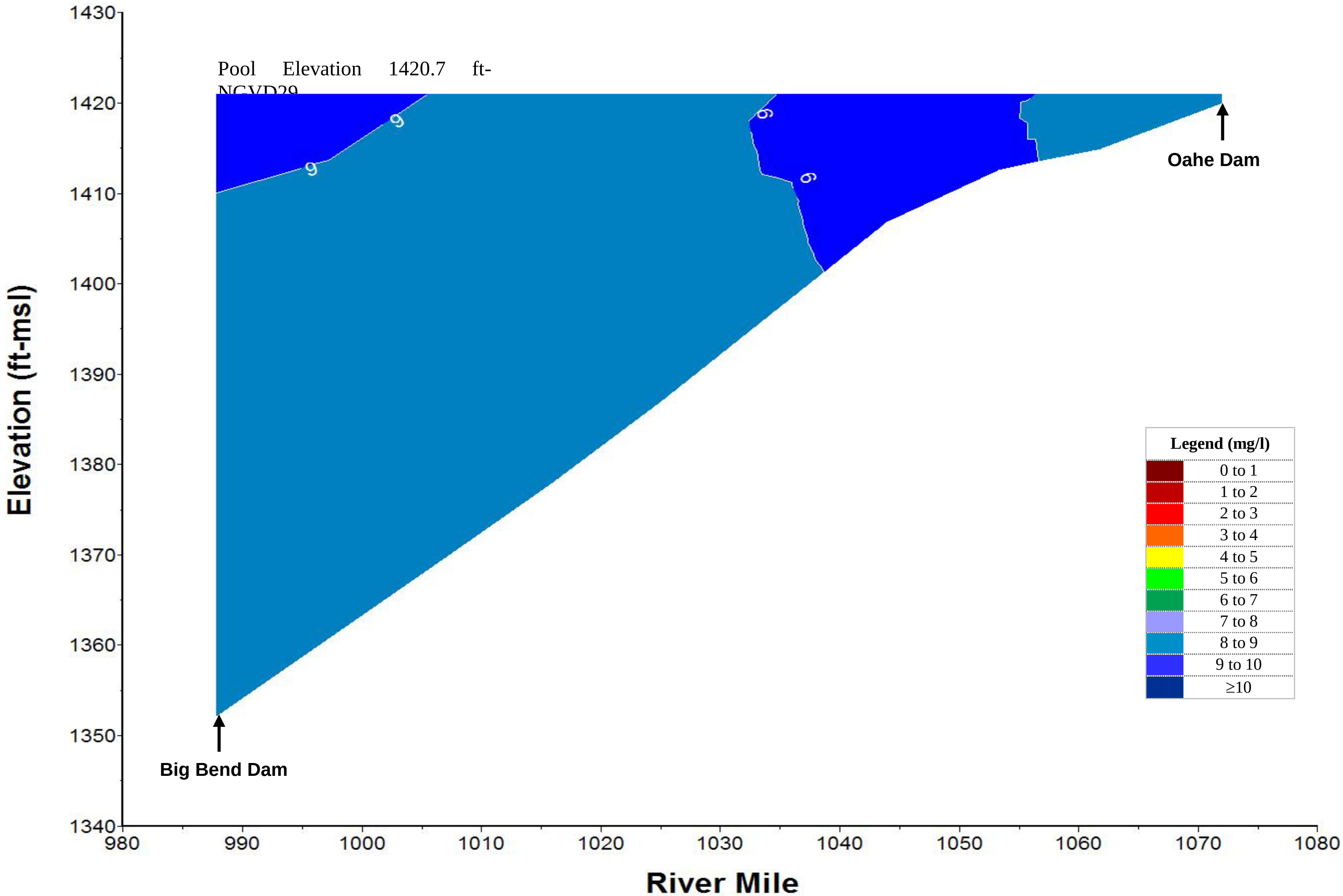

Plate 240. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Sharpe based on depth-profile dissolved oxygen concentrations measured at sites BBDLK0987A, BBDLK1020DW, BBDLK1055DW and OAHPP1 on September 16, 2010.

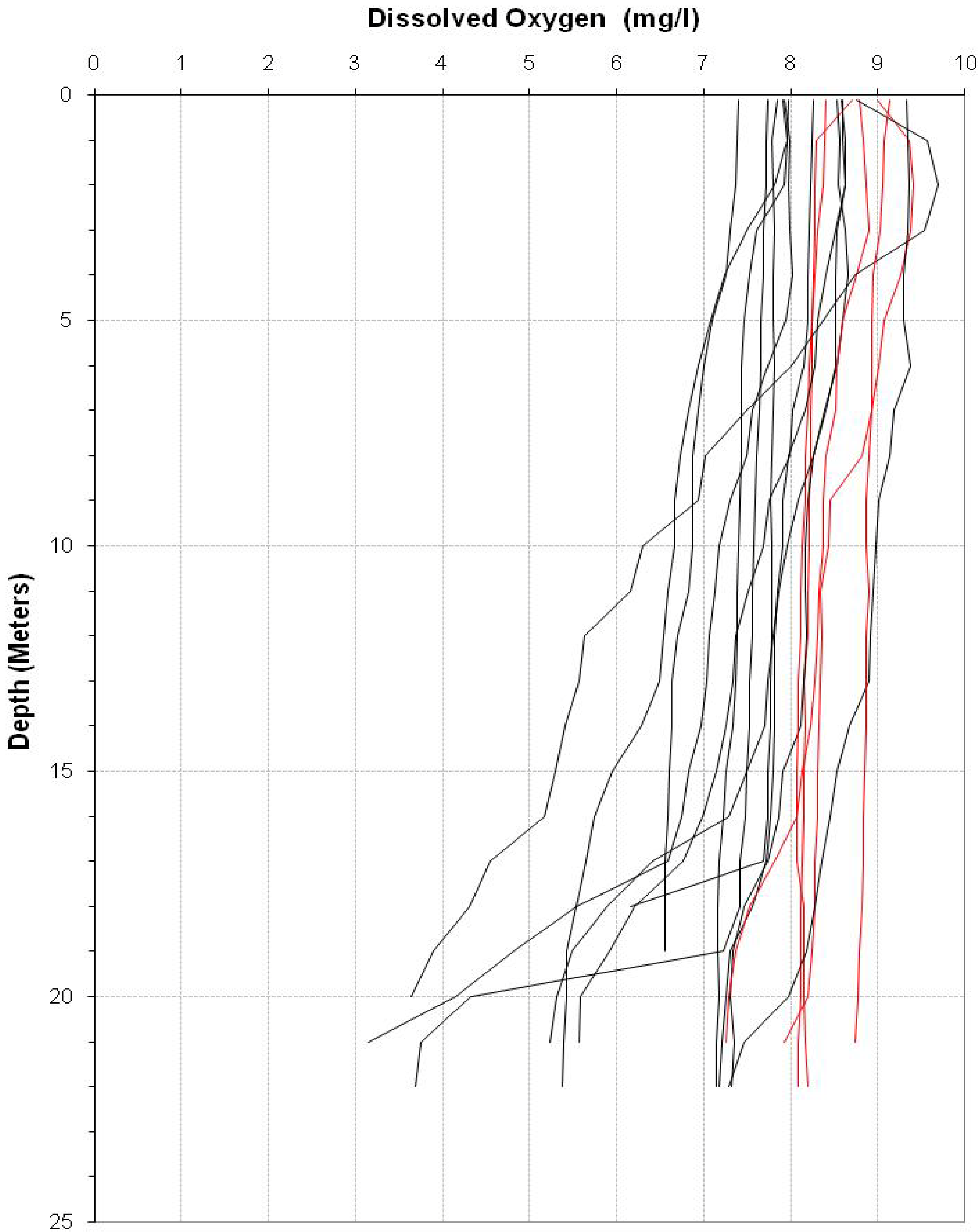

Plate 241. Dissolved oxygen depth profiles for Lake Sharpe generated from data collected at the near-dam, deepwater ambient monitoring site during the summer months of the 5-year period of 2006 through 2010.
(Note: Red profile plots were measured in the month of September.**)**

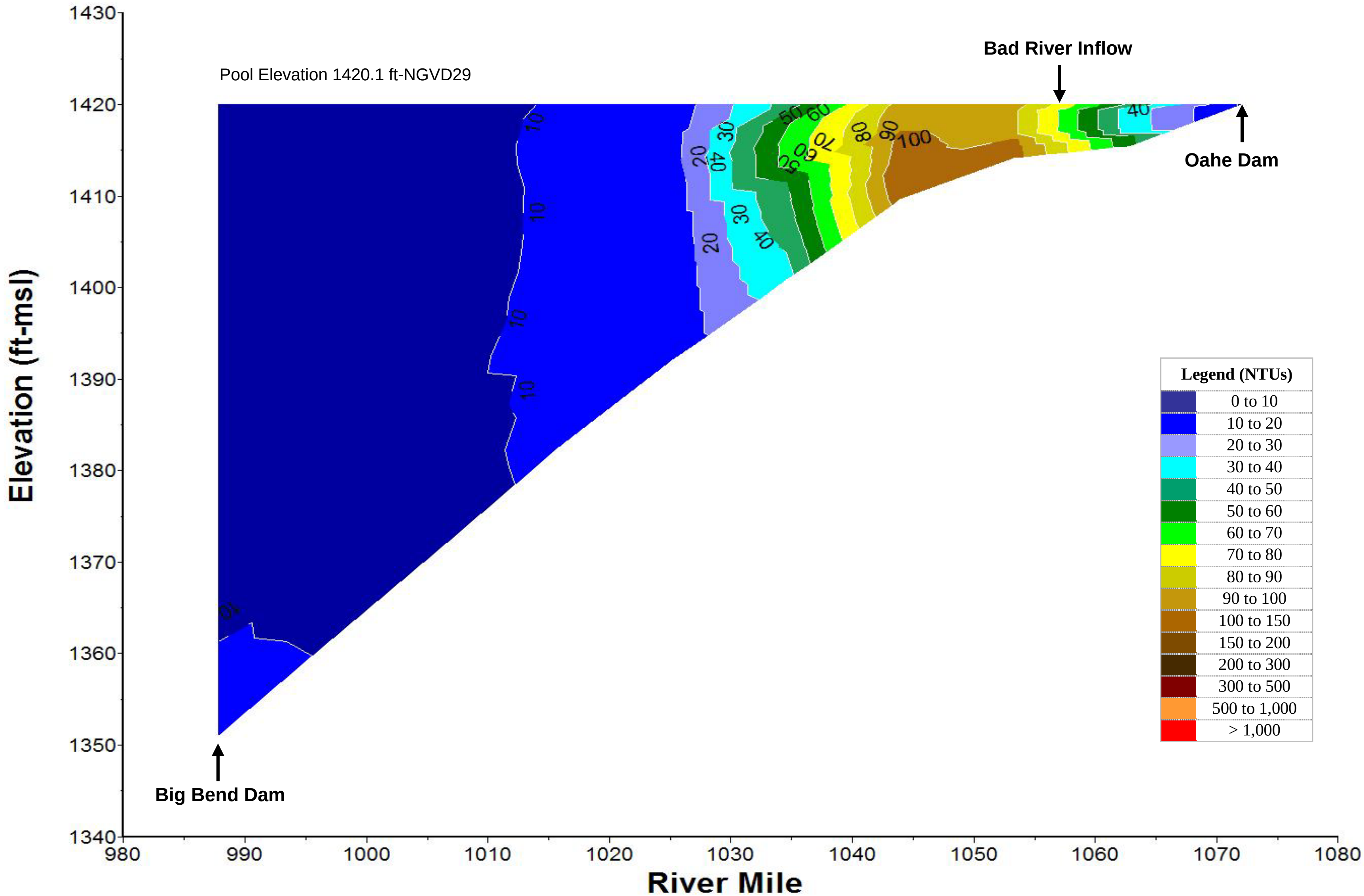

Plate 242. Longitudinal turbidity (NTU) contour plot of Lake Sharpe based on depth-profile turbidity levels measured at sites BBDLK0987A, BBDLK1020DW, BBDLK1055DW, and OAHPP1 on June 16, 2010.

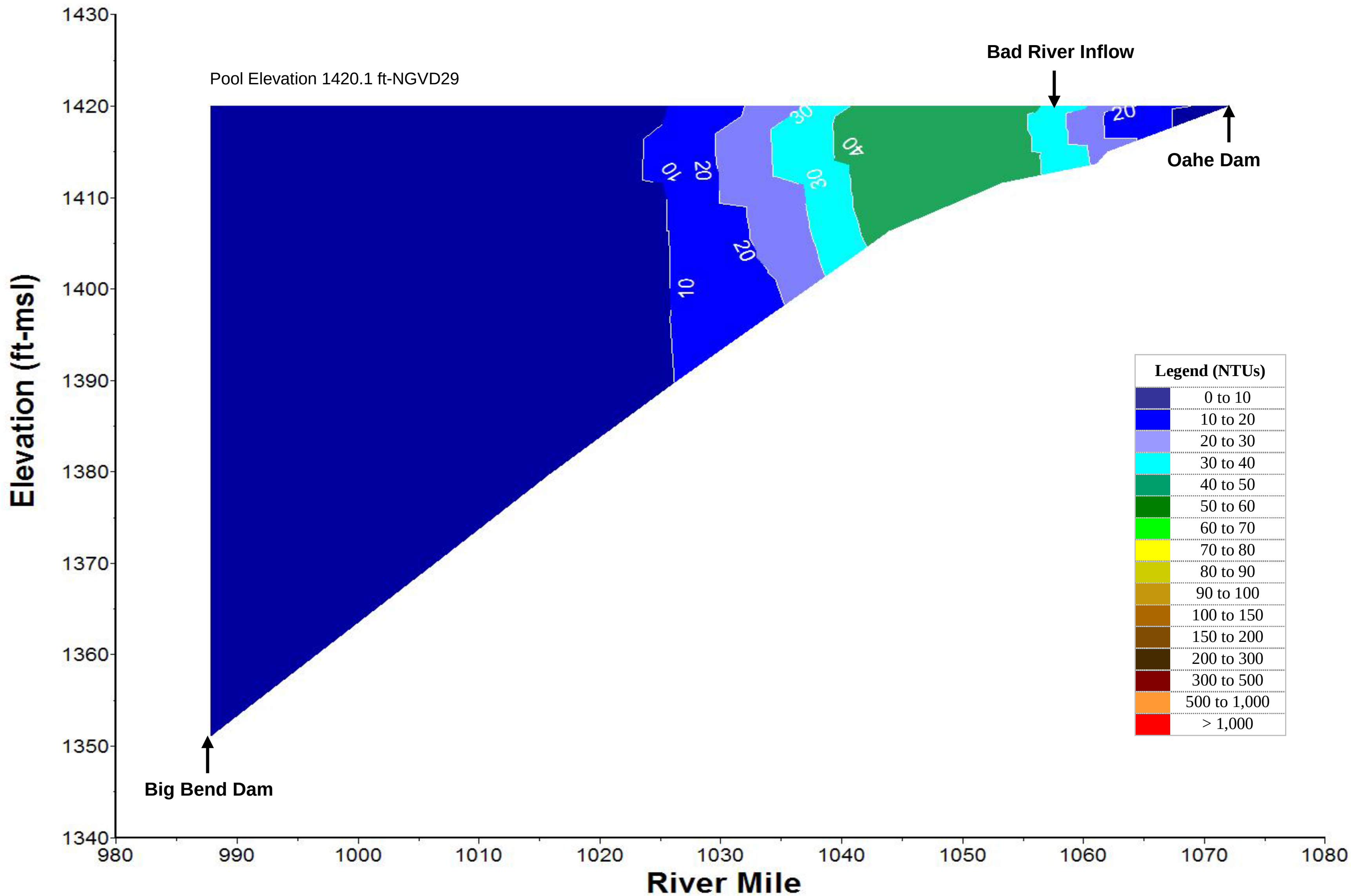

Plate 243. Longitudinal turbidity (NTU) contour plot of Lake Sharpe based on depth-profile turbidity levels measured at sites BBDLK0987A, BBDLK1020DW, BBDLK1055DW, and OAHPP1 on July 14, 2010.

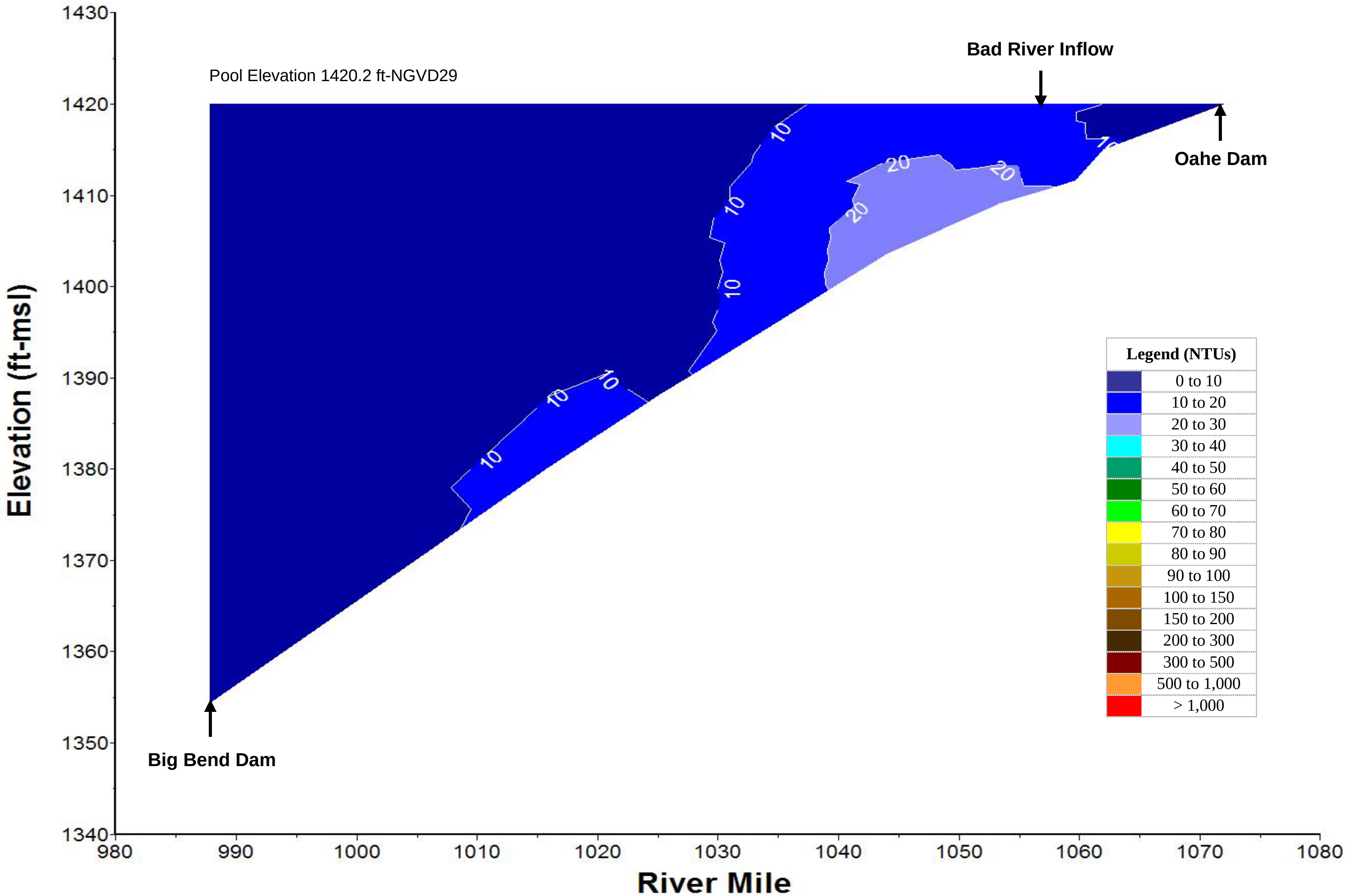

Plate 244. Longitudinal turbidity (NTU) contour plot of Lake Sharpe based on depth-profile turbidity levels measured at sites BBDLK0987A, BBDLK1020DW, BBDLK1055DW, and OAHPP1 on August 11, 2010.

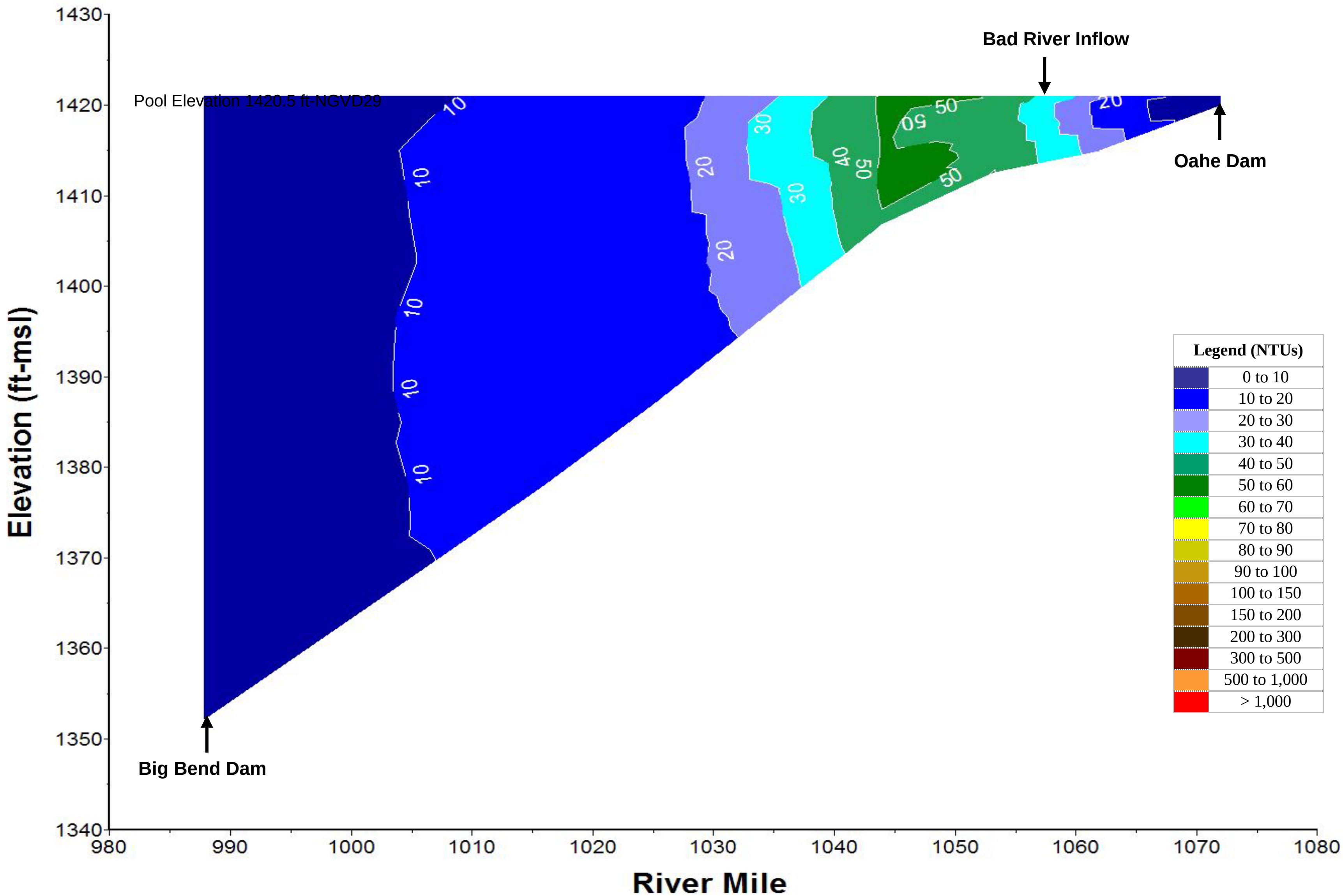

Plate 245. Longitudinal turbidity (NTU) contour plot of Lake Sharpe based on depth-profile turbidity levels measured at sites BBDLK0987A, BBDLK1020DW, BBDLK1055DW, and OAHPP1 on September 16, 2010.

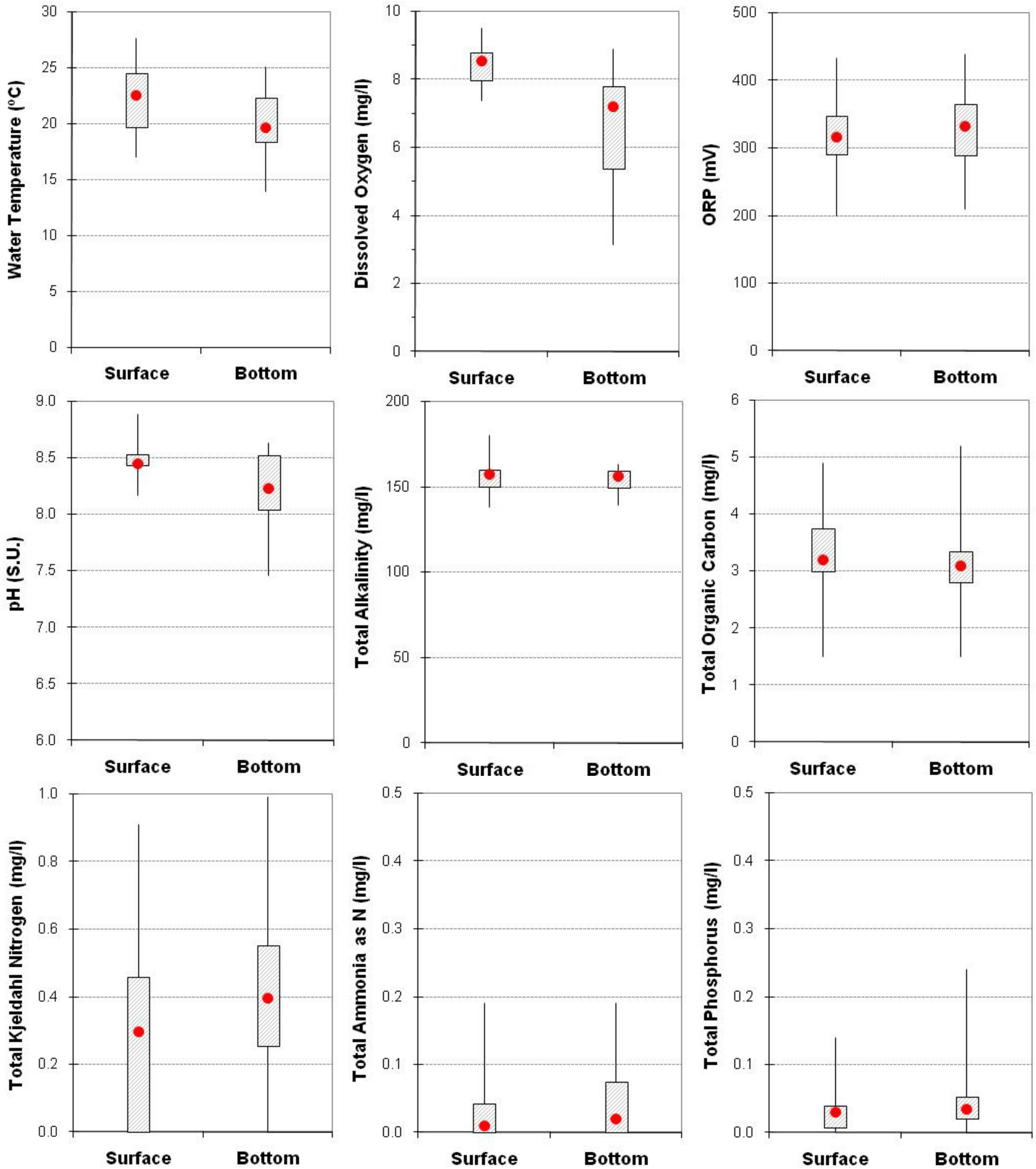

Plate 246. Box plots comparing paired surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus measurements taken in Lake Sharpe at site BBDLK0987A during the summer months of 2006 through 2010.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 247. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected at the near-dam, deepwater ambient monitoring site (i.e., site BBDLK0987A) at Lake Sharpe during the 5-year period 2006 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
May 2006	0.7826	7	0.97	2	<0.01	0	-----	1	<0.01	0	-----	0	-----	1	0.03
Jun 2006	0.5697	7	0.98	8	<0.01	1	<0.01	1	0.02	0	-----	0	-----	0	-----
Jul 2006	0.0710	5	0.13	9	0.41	1	<0.01	1	0.16	3	0.14	1	0.16	0	-----
Aug 2006	0.4602	13	0.71	14	0.15	1	0.01	1	0.01	5	0.06	3	0.06	1	0.01
Sep 2006	0.1120	10	0.51	16	0.25	1	<0.01	1	0.05	7	0.09	2	0.09	1	<0.01
May 2007	0.5695	9	0.95	5	0.01	0	-----	1	0.02	1	<0.01	1	0.02	0	-----
June 2007	0.5179	5	0.74	9	0.10	1	0.13	1	0.02	1	0.01	0	-----	0	-----
July 2007	0.2114	7	0.17	8	0.06	0	-----	2	0.13	4	0.26	1	0.38	0	-----
Aug 2007	0.2698	10	0.20	11	0.22	1	0.03	1	0.04	4	0.42	2	0.10	0	----
Sep 2007	0.1419	6	0.34	12	0.25	0	-----	1	0.18	7	0.15	1	0.07	0	-----
May 2008	0.2285	12	0.97	6	0.01	0	-----	1	0.02	0	-----	1	<0.01	0	-----
Jun 2008	0.2918	6	0.87	5	0.01	1	0.09	1	0.02	1	<0.01	1	0.01	0	-----
Jul 2008	0.0002	3	0.83	2	<0.01	1	0.03	1	0.12	2	0.01	0	-----	1	0.01
Aug 2008	0.0551	3	0.59	4	0.02	2	0.06	1	0.08	4	0.11	2	0.14	0	-----
Sep 2008	0.0107	2	0.08	16	0.55	1	<0.01	2	<0.01	4	<0.01	3	<0.01	0	-----
May 2009	2.2921	7	0.97	3	<0.01	0	-----	1	0.02	0	-----	0	-----	1	<0.01
Jun 2009	0.6403	9	0.36	3	0.20	2	0.04	2	0.40	1	0.01	0	-----	0	-----
Jul 2009	0.1125	12	0.39	7	0.10	1	0.02	1	0.41	2	0.01	1	0.08	0	-----
Aug 2009	0.1002	10	0.23	9	0.19	1	0.12	1	0.25	5	0.12	2	0.10	0	-----
Sep 2009	0.7875	7	0.33	12	0.07	2	<0.01	2	0.41	5	0.02	1	0.16	2	<0.01
May 2010	0.7544	15	1.00	6	<0.01	0	-----	0	-----	0	-----	0	-----	0	-----
Jul 2010	0.3707	6	0.88	8	0.03	0	-----	2	0.04	2	0.03	2	0.02	1	0.01
Sep 2010	0.3919	10	0.84	10	0.05	0	-----	2	0.10	2	<0.01	1	<0.01	0	-----
Mean	**0.4236**	**7.9**	**0.61**	**8.0**	**0.12**	**0.7**	**0.04**	**1.2**	**0.11**	**2.6**	**0.08**	**1.1**	**0.09**	**0.3**	**0.01**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 248. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected at the mid-lake site (i.e., site BBDLK1020DW) at Lake Sharpe during the 3-year period 2008 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	**Percent Comp.**	**No. of Genera**	**Percent Comp.**	**No. of Genera**	**Percent Comp.**	**No. of Genera**	**Percent Comp.**	**No. of Genera**	**Percent Comp.**	**No. of Genera**	**Percent Comp.**	**No. of Genera**	**Percent Comp.**
Jun 2008	0.1121	10	0.88	6	0.01	1	0.01	1	0.10	1	<0.01	0	-----	0	-----
Jul 2008	0.0001	3	0.46	6	0.05	1	0.08	1	0.30	3	0.02	2	0.06	2	0.02
Aug 2008	0.1207	7	0.41	13	0.14	0	-----	1	0.25	7	0.02	2	0.08	2	0.10
Sep 2008	0.0550	7	0.41	6	0.21	0	-----	2	0.37	1	<0.01	1	<0.01	0	-----
Jun 2009	2.4765	6	0.98	2	<0.01	1	<0.01	1	0.02	0	-----	1	<0.01	0	-----
Jul 2009	2.0086	13	0.94	8	0.01	1	<0.01	2	0.05	1	<0.01	1	<0.01	3	<0.01
Aug 2009	1.7067	11	0.83	15	0.08	1	<0.01	1	0.05	4	<0.01	2	0.03	3	<0.01
Sep 2009	1.4041	11	0.67	10	0.05	2	0.05	2	0.20	3	0.01	1	0.02	0	-----
Jul 2010	1.3819	6	0.95	14	0.04	3	<0.01	2	0.01	2	<0.01	1	<0.01	0	-----
Sep 2010	0.4405	6	0.92	9	0.04	1	<0.01	2	0.02	3	0.01	1	0.01	0	-----
Mean	**0.9706**	**8.0**	**0.75**	**8.9**	**0.06**	**1.1**	**0.02**	**1.5**	**0.14**	**2.5**	**0.01**	**1.3**	**0.02**	**1.0**	**0.03**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 249. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in the upstream reaches of Lake Sharpe (i.e., site BBDLK1055DW) during the 3-year period 2008 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	**Percent Comp.**	**No. of Genera**	**Percent Comp.**	**No. of Genera**	**Percent Comp.**	**No. of Genera**	**Percent Comp.**	**No. of Genera**	**Percent Comp.**	**No. of Genera**	**Percent Comp.**	**No. of Genera**	**Percent Comp.**
Jun 2008	0.1113	13	0.96	0	-----	0	-----	1	0.04	0	-----	0	-----	0	-----
Jul 2008	0.0001	7	0.27	4	0.04	1	0.05	1	0.45	0	-----	2	0.18	0	-----
Aug 2008	0.0433	9	0.82	1	0.01	1	0.06	1	0.05	2	<0.01	1	0.06	0	-----
Sep 2008	0.2041	13	0.86	3	0.02	0	-----	2	0.02	2	0.01	1	0.09	0	-----
Jun 2009	0.1767	17	0.95	0	-----	0	-----	1	0.05	1	<0.01	0	-----	0	-----
Jul 2009	0.3163	16	0.95	5	0.04	0	-----	1	0.01	0	-----	0	-----	0	-----
Aug 2009	0.0394	13	0.90	3	0.04	0	-----	1	0.05	1	0.01	0	-----	0	-----
Sep 2009	0.8525	15	0.79	5	0.03	1	<0.01	2	0.18	1	<0.01	0	-----	0	-----
May 2010	0.2792	13	0.95	1	0.05	0	-----	0	-----	0	-----	0	-----	0	-----
Jul 2010	0.6252	12	0.96	2	0.1	0	-----	0	-----	1	<0.01	1	0.01	2	0.02
Sep 2010	0.4151	15	0.99	7	0.01	0	-----	2	<0.01	0	-----	0	-----	1	<0.01
Mean	**0.2785**	**13.0**	**0.85**	**2.8**	**0.04**	**0.3**	**0.04**	**1.1**	**0.09**	**0.7**	**<0.01**	**0.05**	**0.09**	**0.3**	**0.01**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 250. Estimated biomass, number of species, and percent composition (based on biomass) by taxonomic grouping for zooplankton tow samples collected in Lake Sharpe at Sites BBDLK0987A, BBDLK1020DW, and BBDLK1055DW during 2010.

Date	Estimated Biomass (µg/L dry wt.)	Cladocerans		Copepods		Rotifers	
		No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.
Site BBDLK0987A – Near Dam							
May 2010	14.925	0	-----	2	0.79	8	0.21
July 2010	79.281	3	0.86	4	0.12	6	0.02
Sept 2010	11.532	2	0.13	4	0.67	8	0.27
Mean	**35.246**	**1.7**	**0.50**	**3.3**	**0.53**	**7.3**	**0.17**
Site BBDLK1020DW – Iron Nation							
May 2010	No Data						
July 2010	27.954	3	0.26	3	0.50	6	0.24
Sept 2010	6.588	0	-----	4	0.59	5	0.41
Mean	**17.271**	**1.5**	**0.26**	**3.5**	**0.55**	**5.5**	**0.33**
Site BBDLK1055DW – Antelope Creek							
May 2010	No Data						
July 2010	16.107	2	0.13	4	0.85	5	0.02
Sept 2010	15.510	2	0.11	5	0.71	6	0.18
Mean	**15.809**	**2.0**	**0.12**	**4.5**	**0.78**	**5.5**	**0.10**

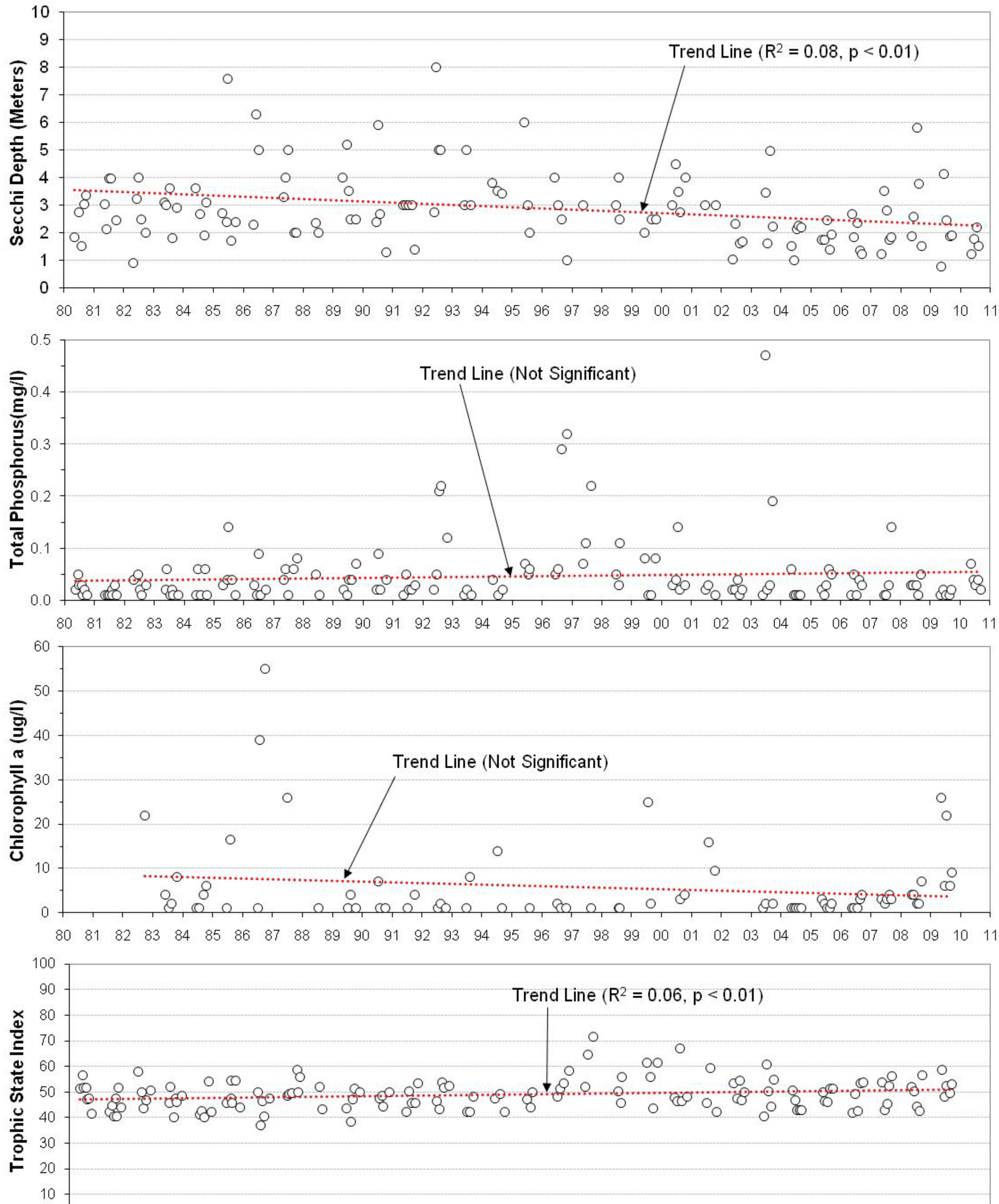

Plate 251. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Lake Sharpe at the near-dam, ambient site (i.e., site BBDLK0987A) over the 31-year period of 1980 through 2010.

Plate 252. Summary of water quality conditions monitored in the Bad River at site BBDNFBADR1 during the 3-year period 2008 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	**No. of Obs.**	**Mean**[B]	**Median**	**Min.**	**Max.**	**State WQS Criteria**[C]	**No. of WQS Exceedances**	**Percent WQS Exceedance**
Flow (cfs)	1	13	404	30	0.2	3,760	-----	-----	-----
Water Temperature (°C)	0.1	13	19.0	19.2	8.3	24.9	27[1,4]	0	0%
Dissolved Oxygen (mg/l)	0.1	13	9.5	8.9	6.8	17.0	5[1,5]	1	2%
Dissolved Oxygen (% Sat.)	0.1	13	103.0	99.5	78.2	145.2	-----	-----	-----
pH (S.U.)	0.1	12	8.2	8.1	7.7	8.8	6.5[1,2,5], 9.0[1,2,4], 9.5[3,4]	0	0%
Specific Conductance (umhos/cm)	1	13	945	755	378	1,745	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	13	350	334	211	552	-----	-----	-----
Turbidity (NTU)	1	13	250	10	2	1,359	-----	-----	-----
Alkalinity, Total (mg/l)	7	15	147	148	116	165	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	15	5.5	5.1	2.5	10.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	15	20	11	3	82	-----	-----	-----
Chloride, Dissolved (mg/l)	1	9	22	13	9	74	175[1,4], 100[1,6], 438[2,4], 250[2,6]	0	0%
Dissolved Solids, Total (mg/l)	5	15	685	616	360	1,226	1,750[2,4], 1,000[2,7], 3,500[3,4], 2,000[3,6]	0, 3, 0, 0	0%, 20%, 0%, 0%
Iron, Total (ug/l)	40	8	12,038	320	210	93,000	-----	-----	-----
Manganese, Total (ug/l)	2	8	670	20	20	5,060	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	15	-----	0.03	n.d.	0.34	7.0 [1,4,7], 1.5[1,6,7]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	15	1.0	0.9	0.3	3.3	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	15	-----	0.12	n.d.	2.30	10[2,4]	0	0%
Nitrogen, Total (mg/l)	0.1	15	1.3	0.9	0.3	3.7	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	15	-----	0.03	n.d.	0.09	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	15	0.26	0.05	n.d.	2.90	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	15	-----	0.02	n.d.	0.06	-----	-----	-----
Sulfate (mg/l)	1	15	315	225	135	630	875[2,4], 500[2,6]	0, 3	0%, 20%
Suspended Solids, Total (mg/l)	4	15	275	26	n.d.	3,478	158[1,4], 90[1,6]	3, 3	20%, 20%
Pesticide Scan (ug/l)[D]	0.05[E]						-----	-----	-----

n.d. = Not detected, b.d. = Criterion below detection limit.

[A] Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

[1] Criteria for the protection of warmwater permanent fish life propagation waters.
[2] Criteria for the protection of domestic water supply waters.
[3] Criteria for the protection of commerce and industry waters.
[4] Daily maximum criterion (monitoring results directly comparable to criterion).
[5] Daily minimum criterion (monitoring results directly comparable to criterion).
[6] 30-day average criterion (monitoring results not directly comparable to criterion).
[7] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

[D] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

[E] Detection limits vary by pesticide – 0.05 ug/l is a median detection limit for the pesticides in the pesticide scan.

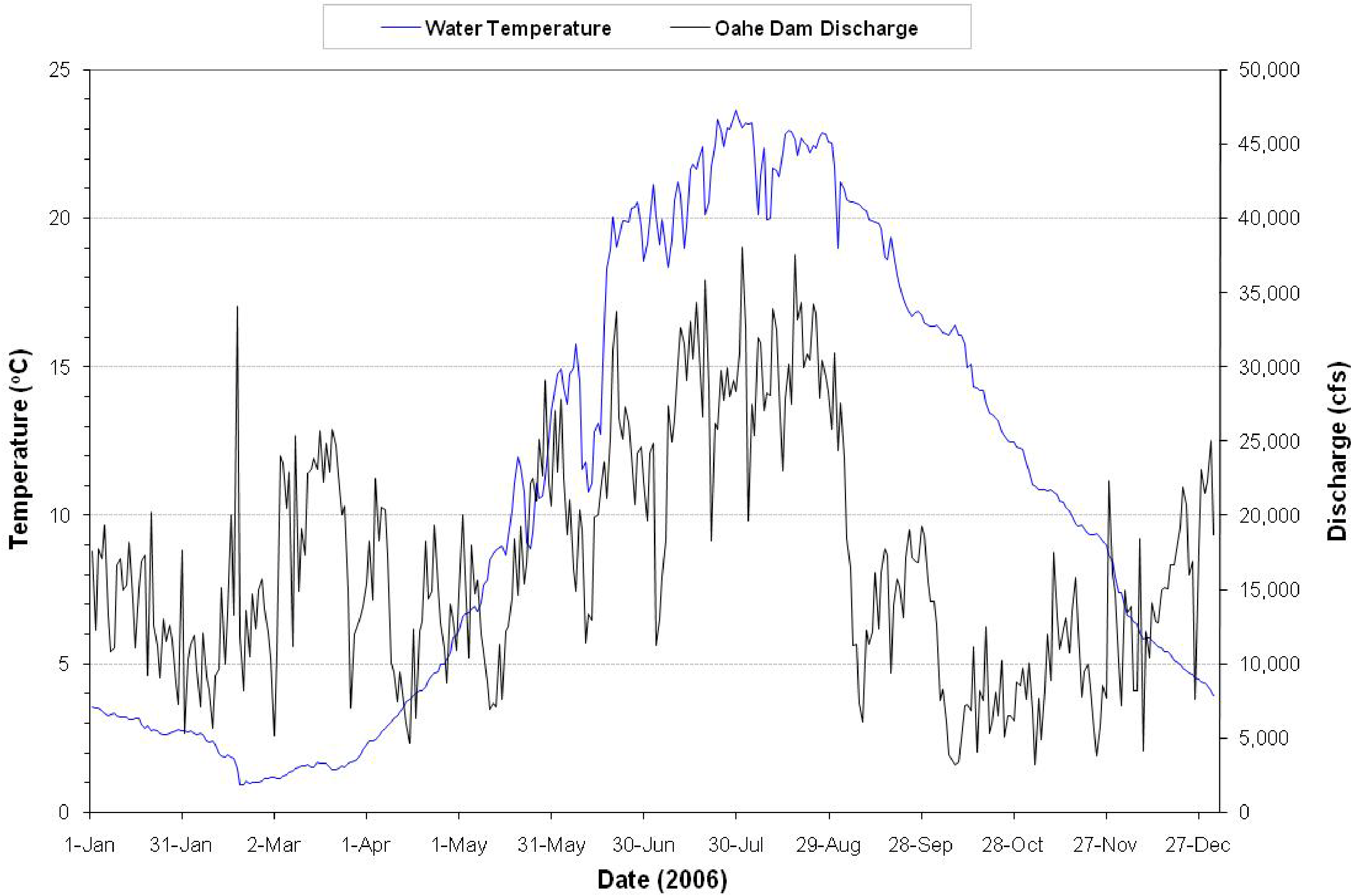

Plate 253. Mean daily water temperature and discharge of the Missouri River at Oahe Dam (i.e., site OAHPP1) for 2006. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Oahe Dam.

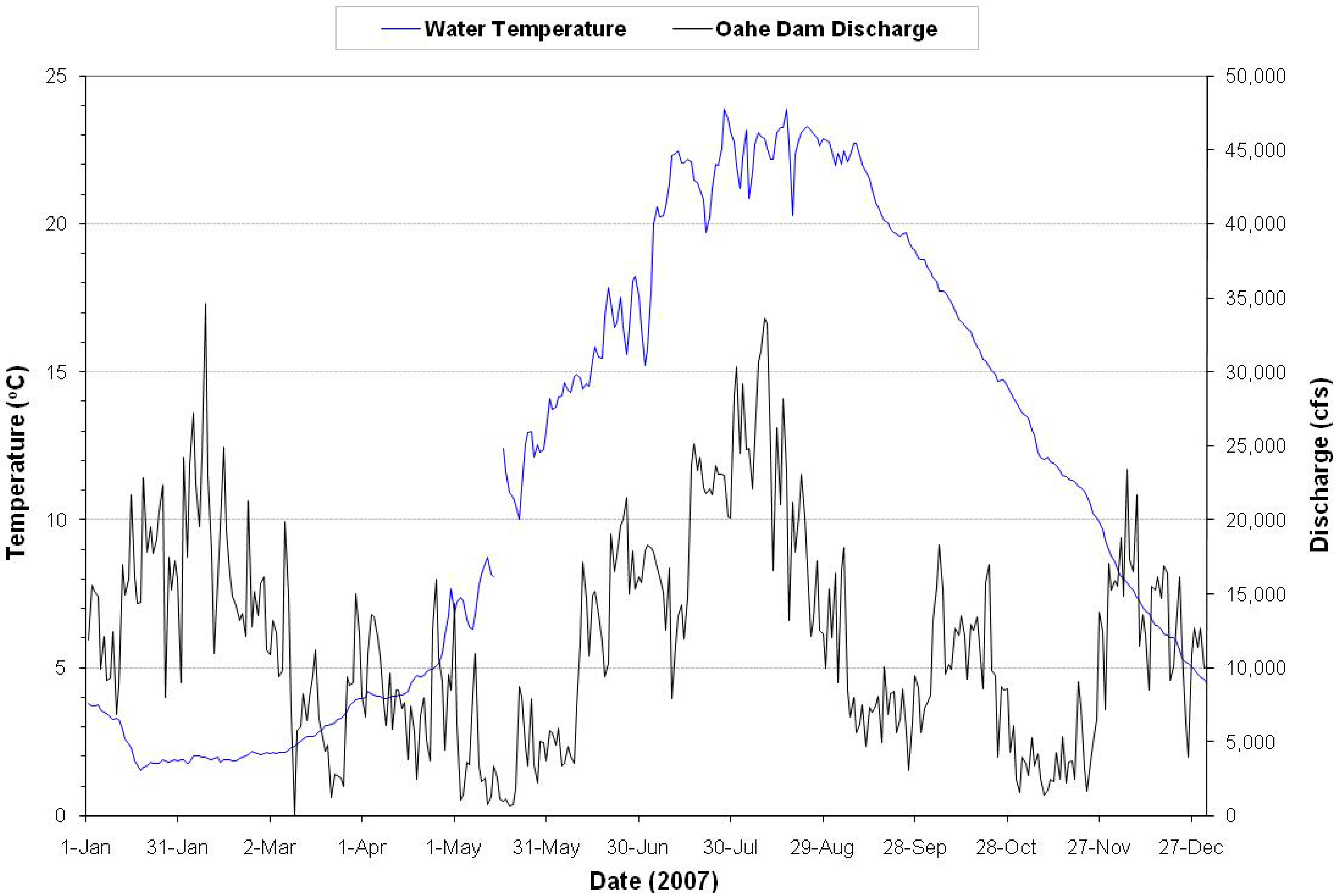

Plate 254. Mean daily water temperature and discharge of the Missouri River at Oahe Dam (i.e., site OAHPP1) for 2007. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Oahe Dam.

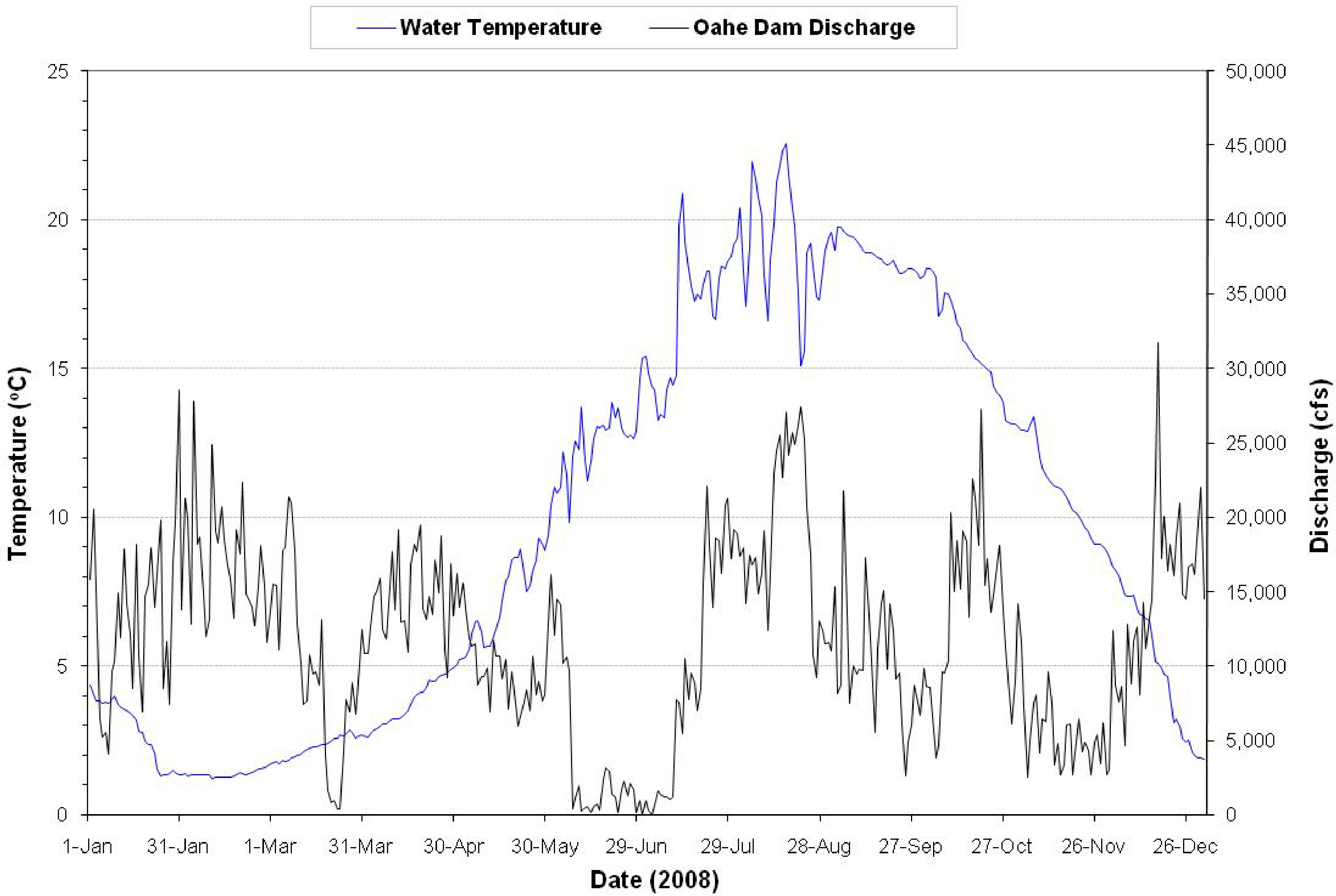

Plate 255. Mean daily water temperature and discharge of the Missouri River at Oahe Dam (i.e., site OAHPP1) for 2008. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Oahe Dam.

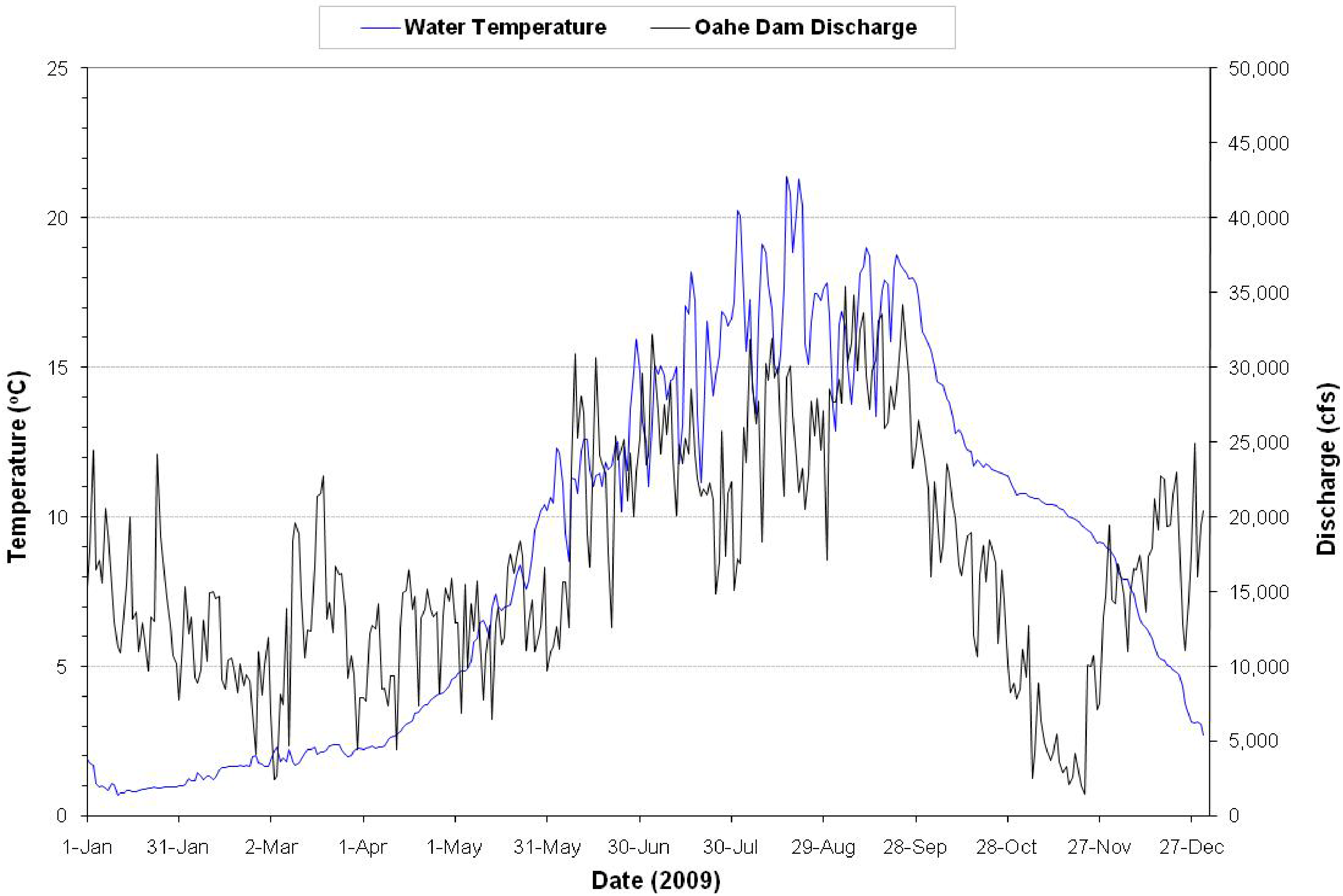

Plate 256. Mean daily water temperature and discharge of the Missouri River at Oahe Dam (i.e., site OAHPP1) for 2009. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Oahe Dam.

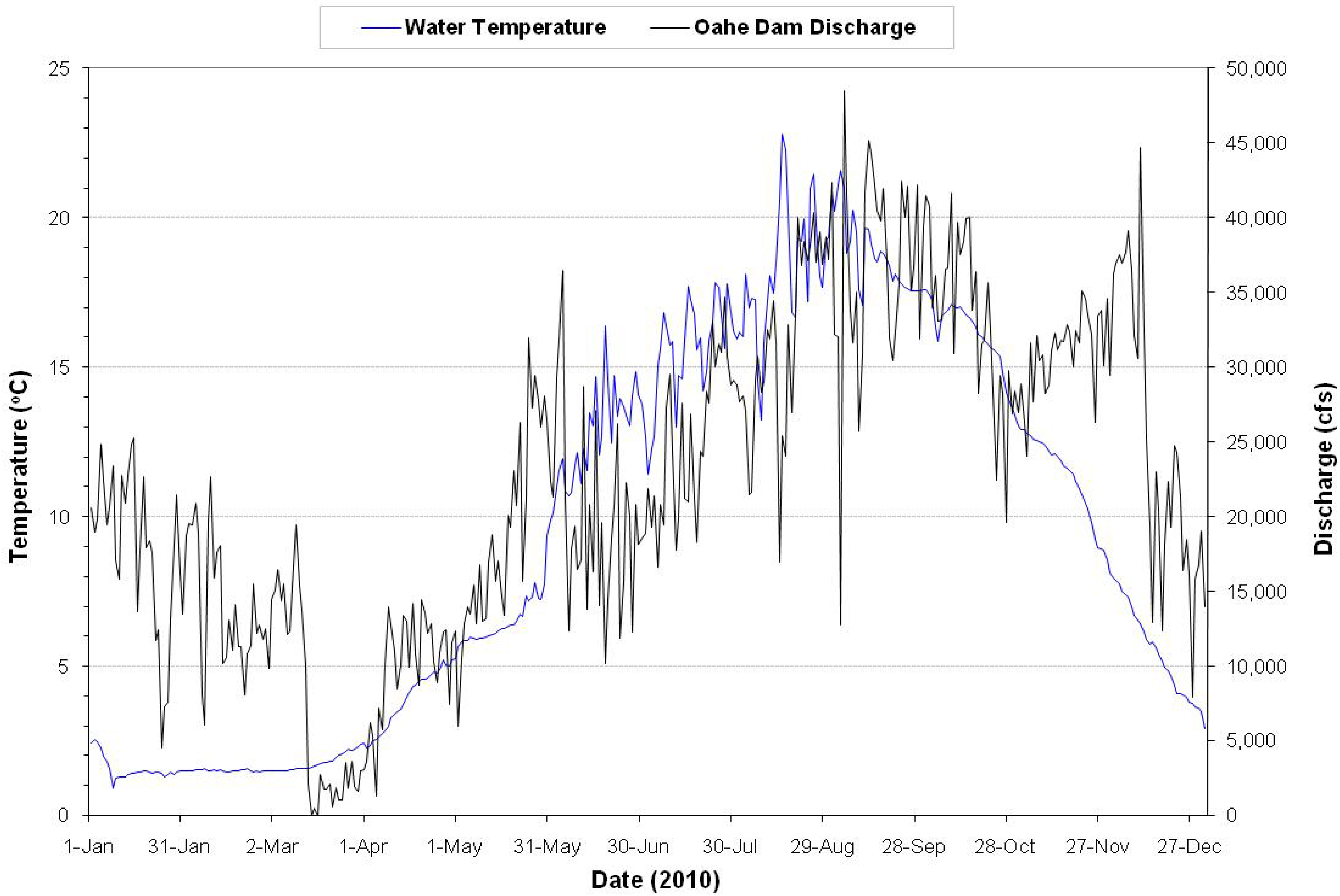

Plate 257. Mean daily water temperature and discharge of the Missouri River at Oahe Dam (i.e., site OAHPP1) for 2010. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Oahe Dam.

Plate 258. Summary of water quality conditions monitored on water discharged through Big Bend Dam powerplant (i.e., site BBDPP1) during the 5-year period of 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Dam Discharge (cfs)	1	47	26,982	23,600	0	71,717	-----	-----	-----
Water Temperature (°C)	0.1	49	12.4	11.0	0.5	25.4	27(1,2)	0	0%
Dissolved Oxygen (mg/l)	0.1	48	9.9	9.7	5.5	15.0	5(1,3)	0	0%
Dissolved Oxygen (% Sat.)	0.1	48	93.1	94.4	68.3	113.9	-----	-----	-----
pH (S.U.)	0.1	46	8.2	8.3	7.2	8.8	6.5(1,3), 9.0(1,2)	0	0%
Specific Conductance (umhos/cm)	1	48	708	707	642	864	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	39	365	356	177	714	-----	-----	-----
Turbidity (NTU)	1	40	9	3	n.d.	82	-----	-----	-----
Alkalinity, Total (mg/l)	7	49	161	160	116	195	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	48	3.4	3.2	1.4	5.7	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	49	11	10	n.d.	33	-----	-----	-----
Chloride, Dissolved (mg/l)	1	39	12	12	9	25	438(2,4), 250(2,6)	0	0%
Color, True (APHA)	1	8	10	6	5	23	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	49	476	476	378	592	1,750(2,4), 1,000(2,7), 3,500(3,4), 2,000(3,6)	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	49	-----	n.d.	n.d.	0.31	4.7 (1,4,7), 1.4 (1,6,7)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	48	0.6	0.5	n.d.	1.7	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	49	-----	n.d.	n.d.	1.00	10(2,4)	0	0%
Nitrogen, Total (mg/l)	0.1	48	0.6	0.5	n.d.	1.7	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	47	-----	0.02	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	48	-----	0.03	n.d.	0.15	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	49	-----	n.d.	n.d.	0.06	-----	-----	-----
Sulfate (mg/l)	1	49	202	205	172	237	875(2,4), 500(2,6)	0	0%
Suspended Solids, Total (mg/l)	4	48	-----	n.d.	n.d.	67	158(1,4), 90(1,6)	0	0%

n.d. = Not detected, b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of warmwater permanent fish life propagation waters.
(2) Criteria for the protection of domestic water supply waters.
(3) Criteria for the protection of commerce and industry waters.
(4) Daily maximum criterion (monitoring results directly comparable to criterion).
(5) Daily minimum criterion (monitoring results directly comparable to criterion).
(6) 30-day average criterion (monitoring results not directly comparable to criterion).
(7) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

Plate 259. Summary of annual metals and pesticide levels monitored on water discharged through Big Bend Dam (i.e., site BBDPP1) during the 5-year period of 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Aluminum, Total (ug/l)	25	4	316	195	127	745	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	0.6	-----	-----	-----
Antimony, Total (ug/l)	0.5	4	-----	n.d.	n.d.	0.7	5.6[3]	0	0%
Arsenic, Dissolved (ug/l)	1	4	1	1	1	2	340[1], 150[2]	0, 0	0%, 0%
Arsenic, Total (ug/l)	1	4	2	2	2	2	0.018[3]	4	100%
Barium, Dissolved (ug/l)	5	4	42	43	37	46	-----	-----	-----
Barium, Total (ug/l)	5	4	48	51	40	52	-----	-----	-----
Beryllium, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Beryllium, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	4[3]	0	0%
Cadmium, Dissolved (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	4.3[1], 0.42[2]	0	0%
Cadmium, Total (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	5[3]	0	0%
Chromium, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	n.d.	1,075[1], 140[2]	0	0%
Chromium, Total (ug/l)	10	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Copper, Dissolved (ug/l)	2	6	-----	n.d.	n.d.	n.d.	28[1], 17[2],	0	0%
Copper, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	1,300[3]	0	0%
Hardness, Total (mg/l)	0.4	5	210	210	169	238	-----	-----	-----
Iron, Dissolved (ug/l)	7	7[A]	-----	n.d.	n.d.	10	-----	-----	-----
Iron, Total (ug/l)	7	15[A]	213	150	20	553	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	148[1], 5.8[2]	0	0%
Lead, Total (ug/l)	0.5	4	-----	n.d.	n.d.	6	-----	-----	-----
Manganese, Dissolved (ug/l)	2	16[A]	-----	2	n.d.	15	-----	-----	-----
Manganese, Total (ug/l)	2	16[A]	67	42	n.d.	315	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	6	-----	n.d.	n.d.	n.d.	1.4[1]	0	0%
Mercury, Total (ug/l)	0.05	6	-----	n.d.	n.d.	n.d.	0.77[2], 0.05[3]	0	0%
Nickel, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	n.d.	902[1], 100[2]	0	0%
Nickel, Total (ug/l)	10	4	-----	n.d.	n.d.	n.d.	610[3]	0	0%
Selenium, Total (ug/l)	1	4	2	2	1	2	4.6[2], 170[3]	0	0%
Silver, Dissolved (ug/l)	1	6	-----	n.d.	n.d.	n.d.	12[1]	0	0%
Silver, Total (ug/l)	1	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Total (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	0.24[3]	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	10	226[1,2]	0	0%
Zinc, Total (ug/l)	10	4	-----	19	n.d.	50	7,400[3]	0	0%
Pesticide Scan (ug/l)[D]	0.05[E]	5	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected, b.d. = Criterion below detection limit.

[A] Results for iron (dissolved and total) and manganese (dissolved and total) include some monthly samples.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

[1] Acute (CMC) criterion for the protection of freshwater aquatic life.

[2] Chronic (CCC) criterion for the protection of freshwater aquatic life.

[3] Criterion for the protection of human health.

Note: Some of South Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

[E] Detection limits vary by pesticide – 0.05 ug/l is a median detection limit for the pesticides in the pesticide scan.

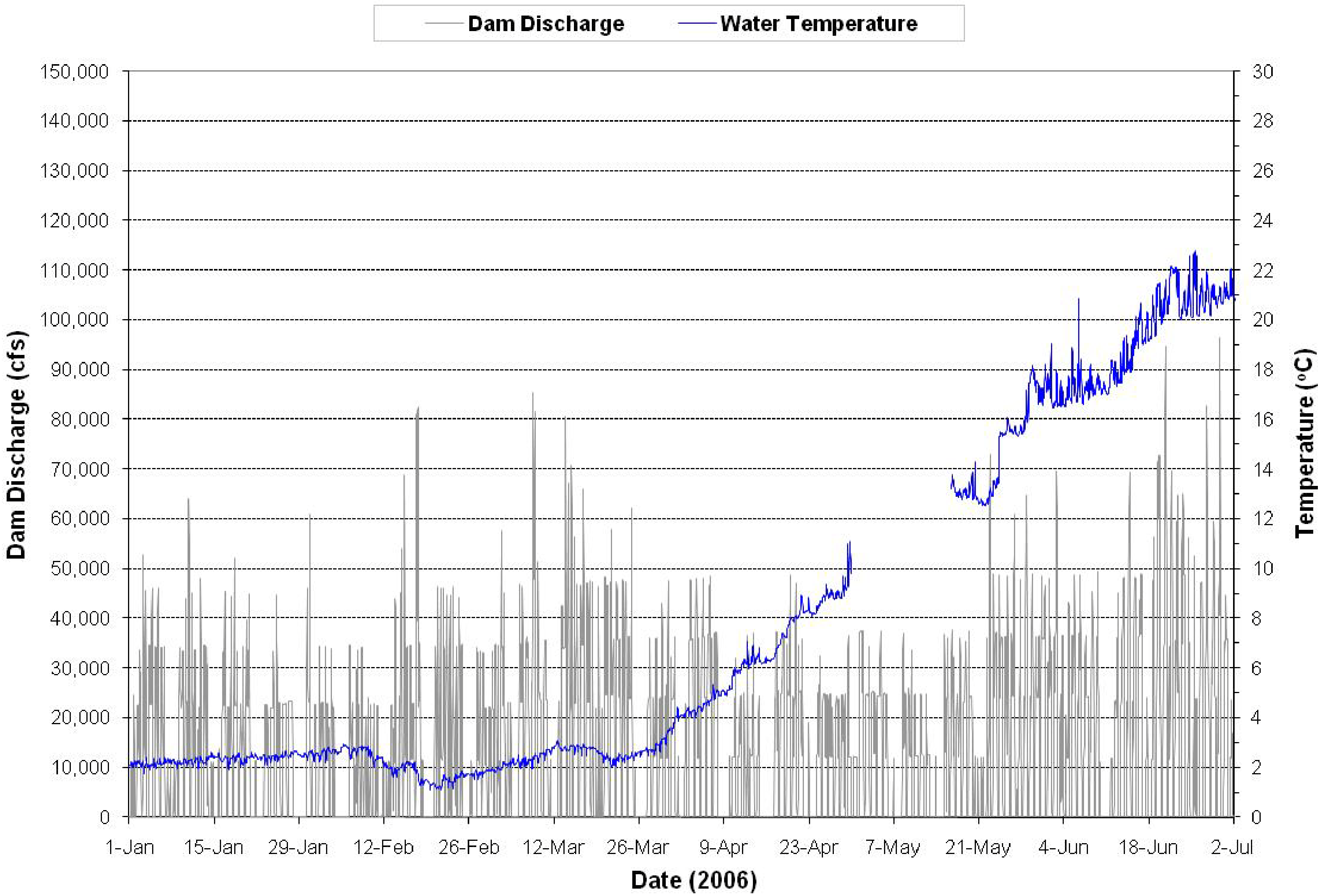

Plate 260. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period January through June 2006.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

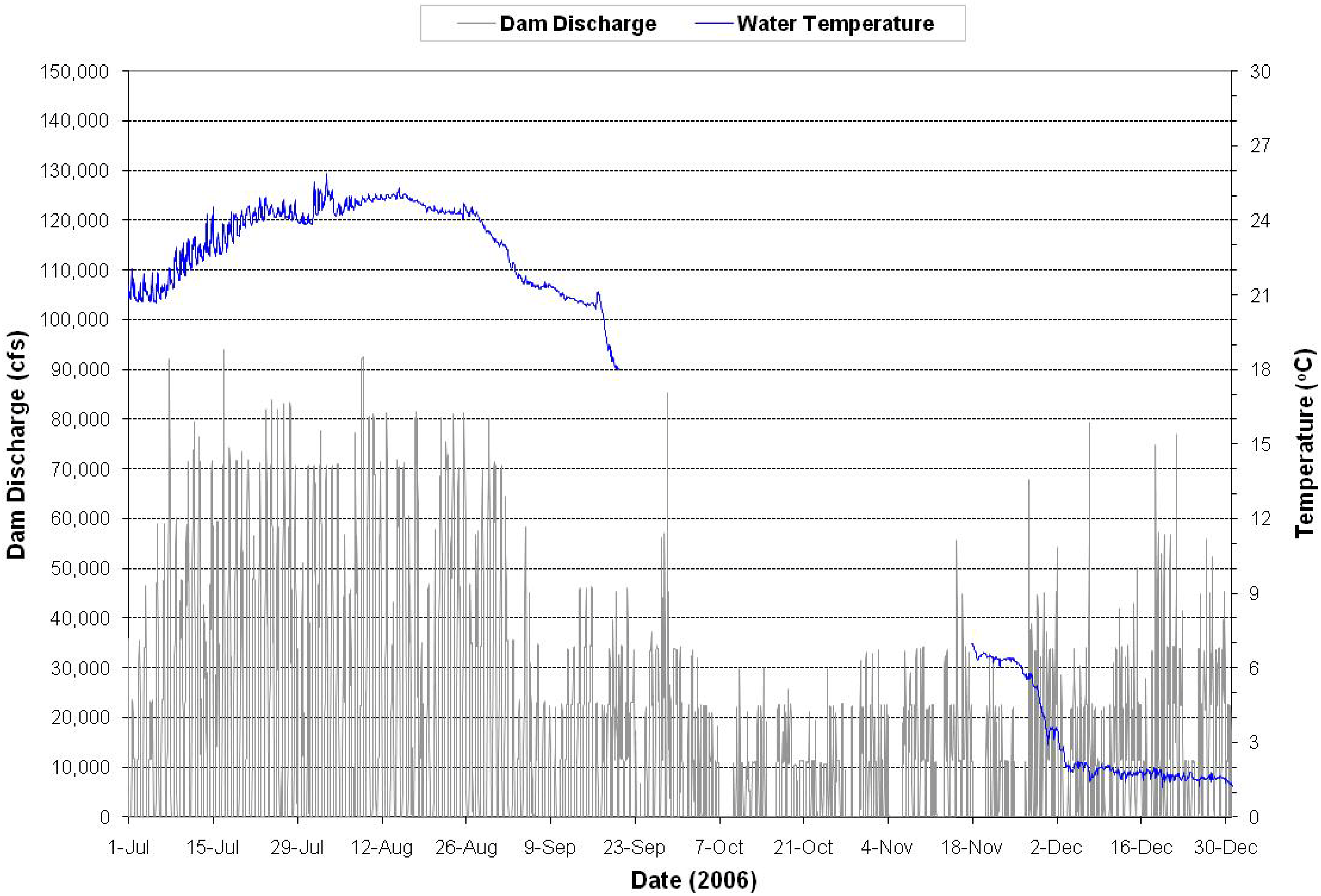

Plate 261. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2006.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

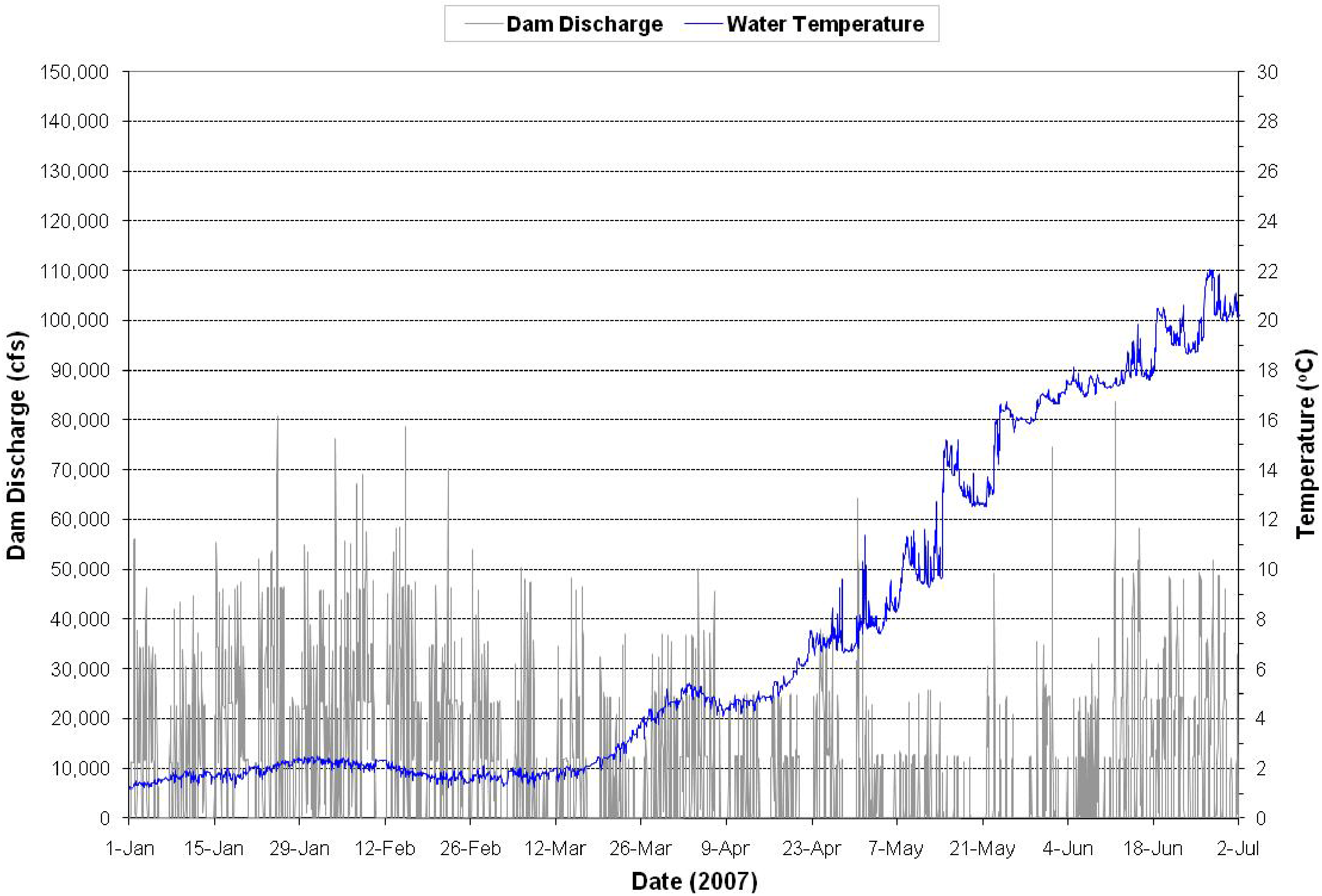

Plate 262. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period January through June 2007.

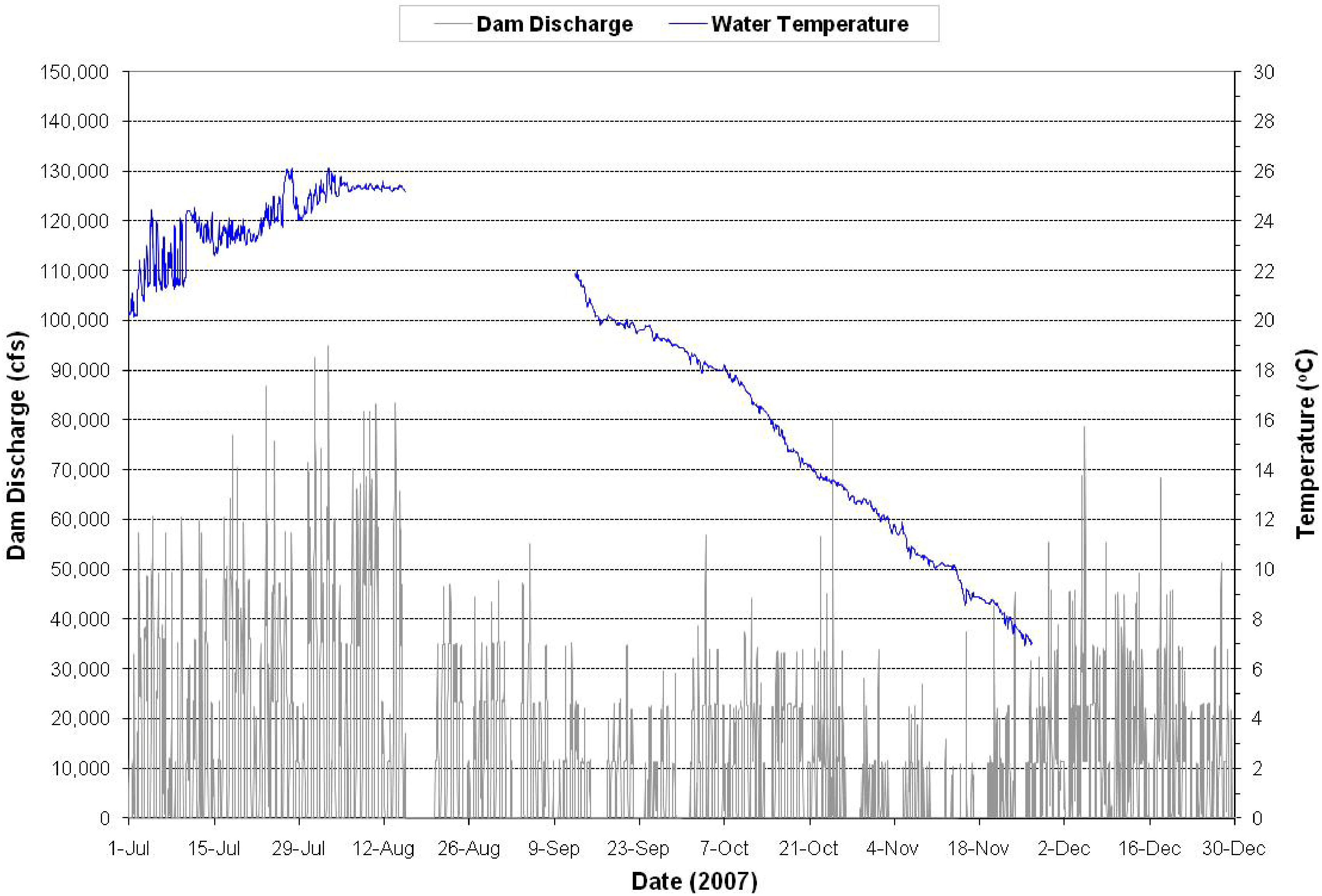

Plate 263. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

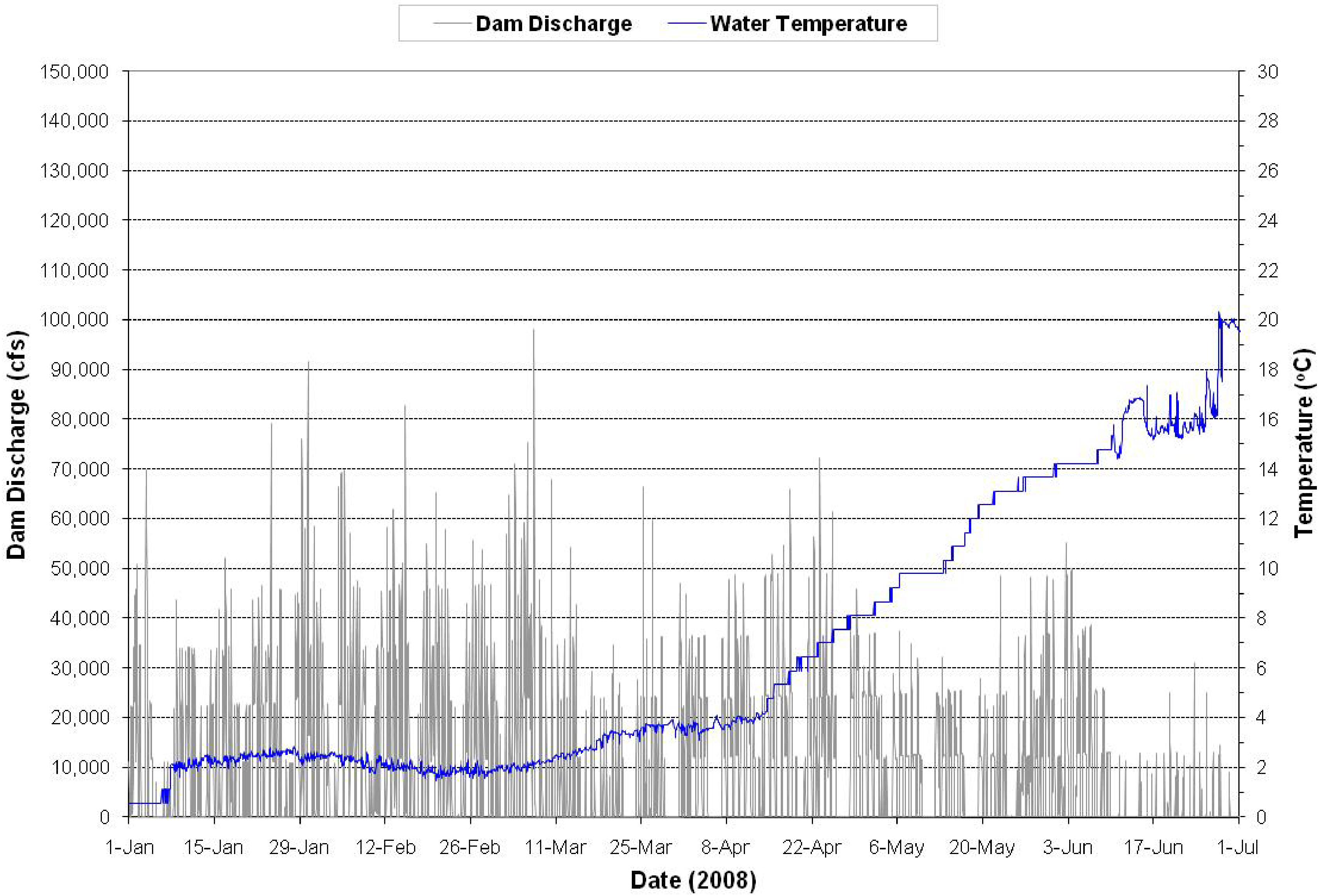

Plate 264. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period January through June 2008.

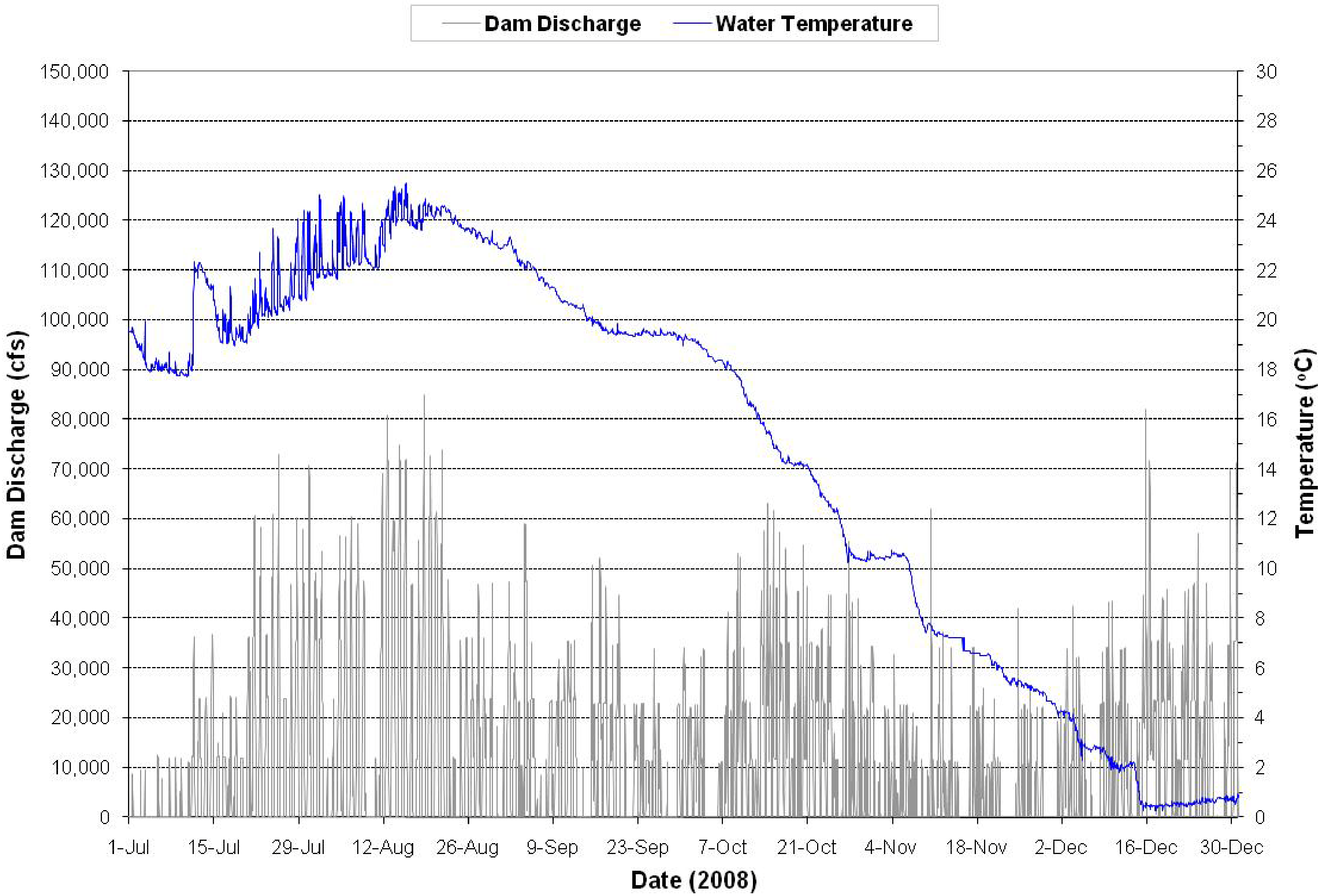

Plate 265. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2008.

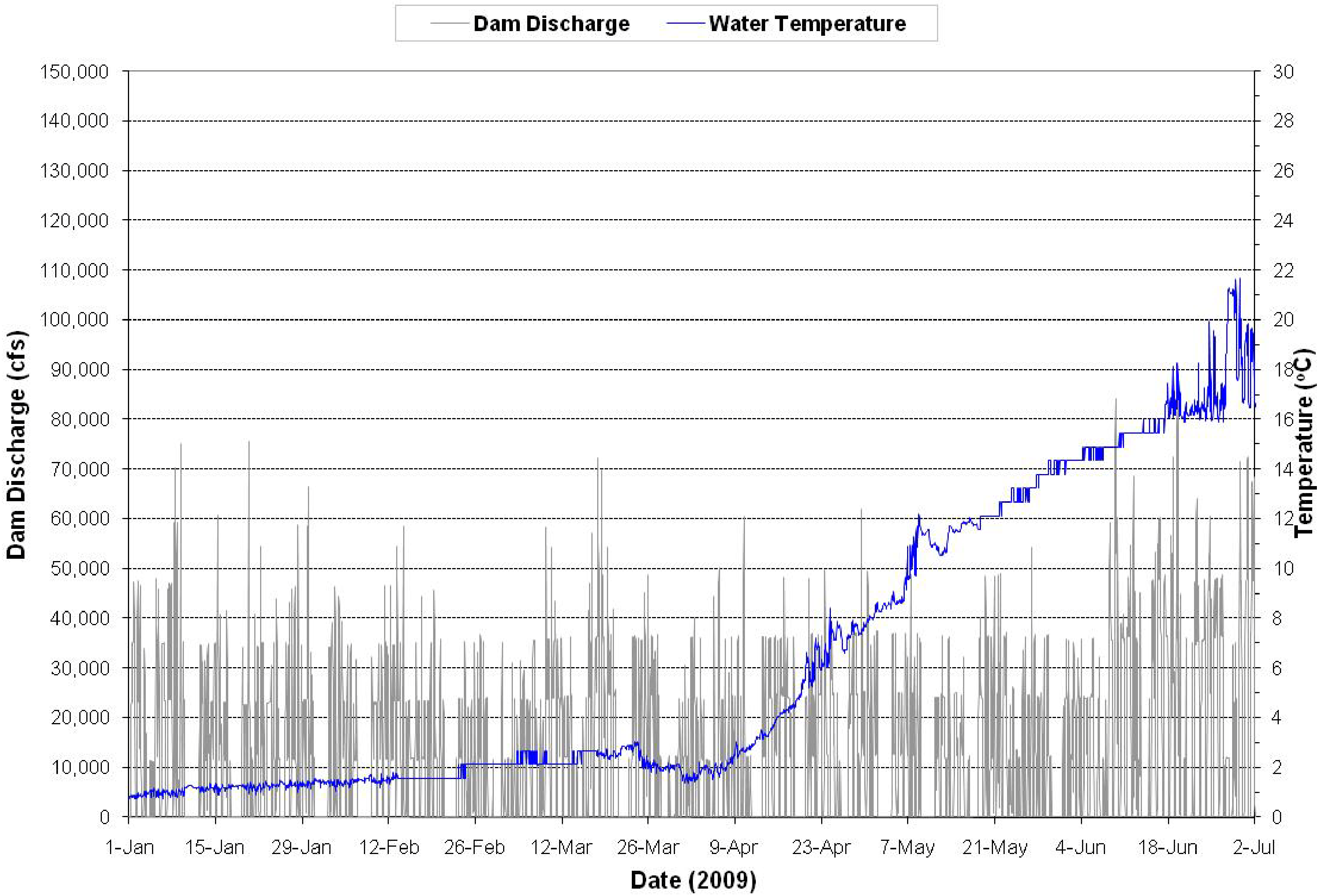

Plate 266. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period January through June 2009.

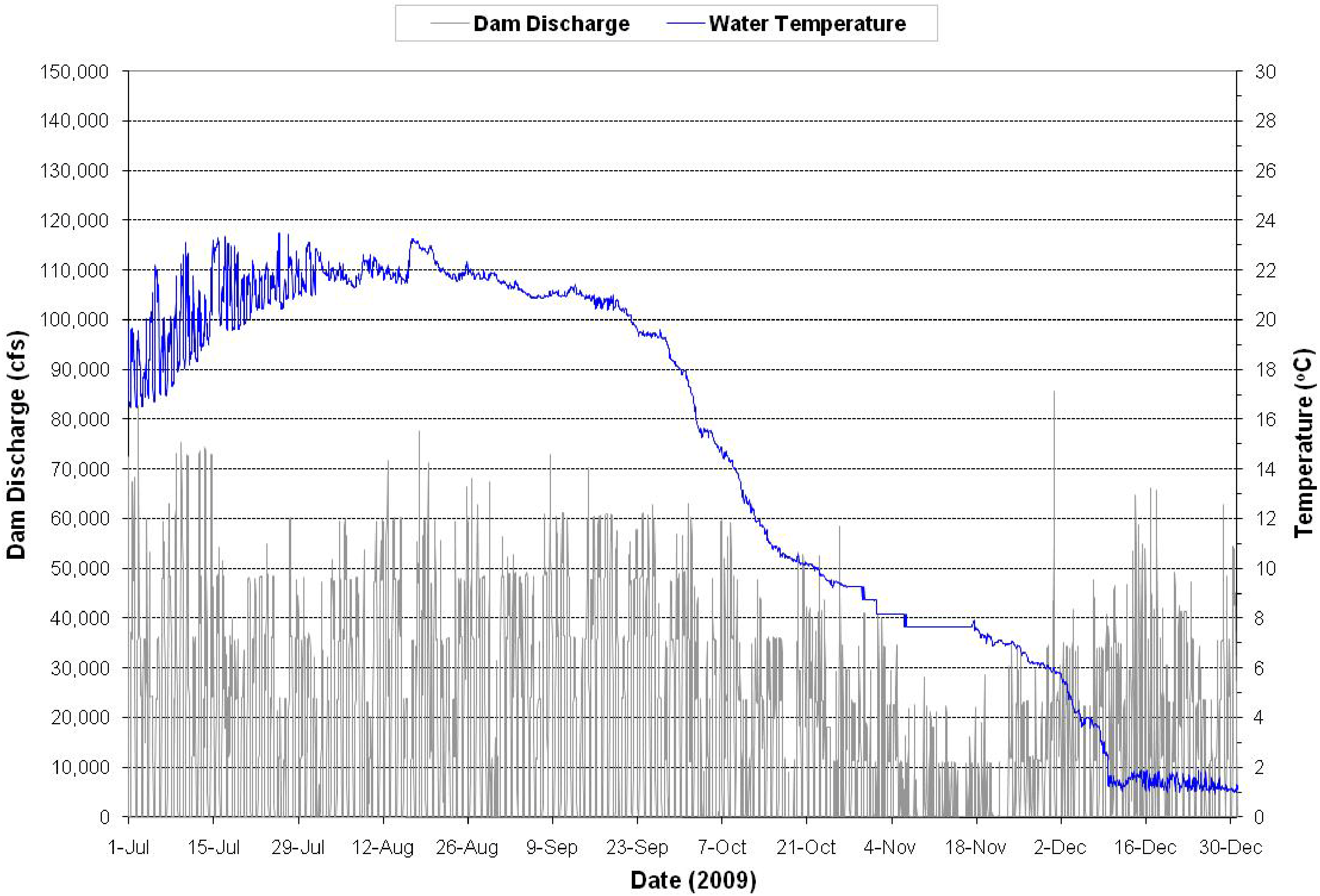

Plate 267. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2009.

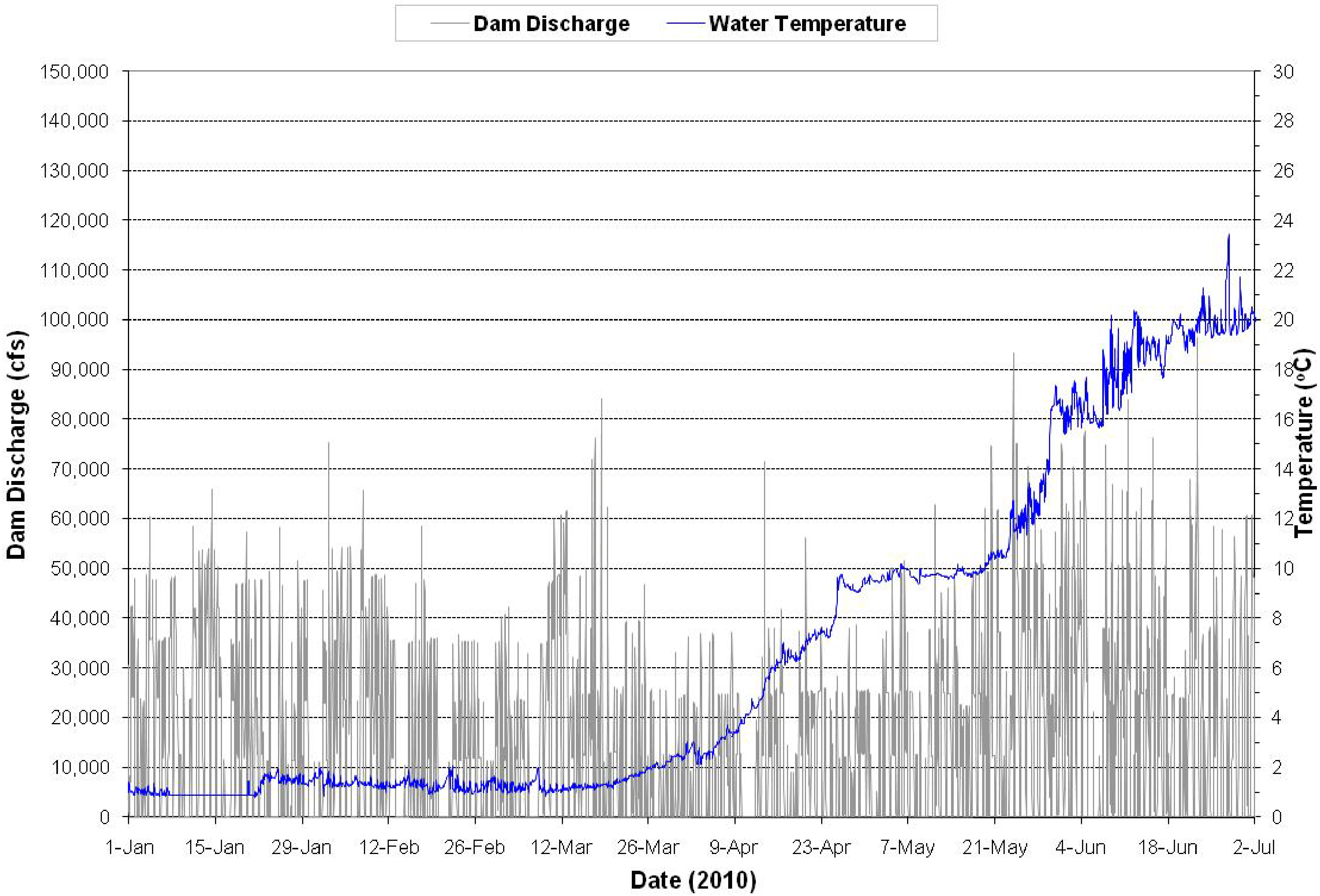

Plate 268. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period January through June 2010.

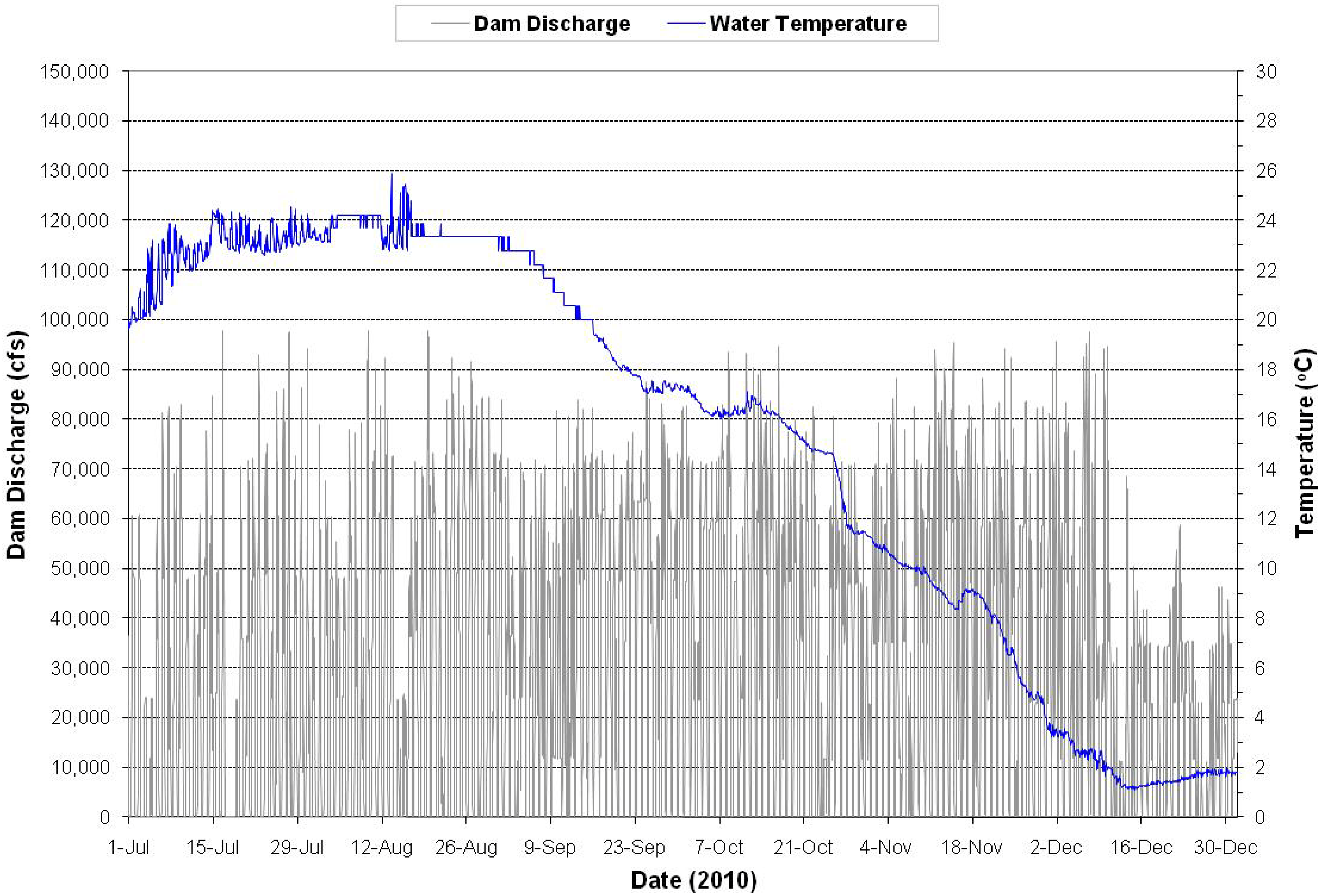

Plate 269. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2010.

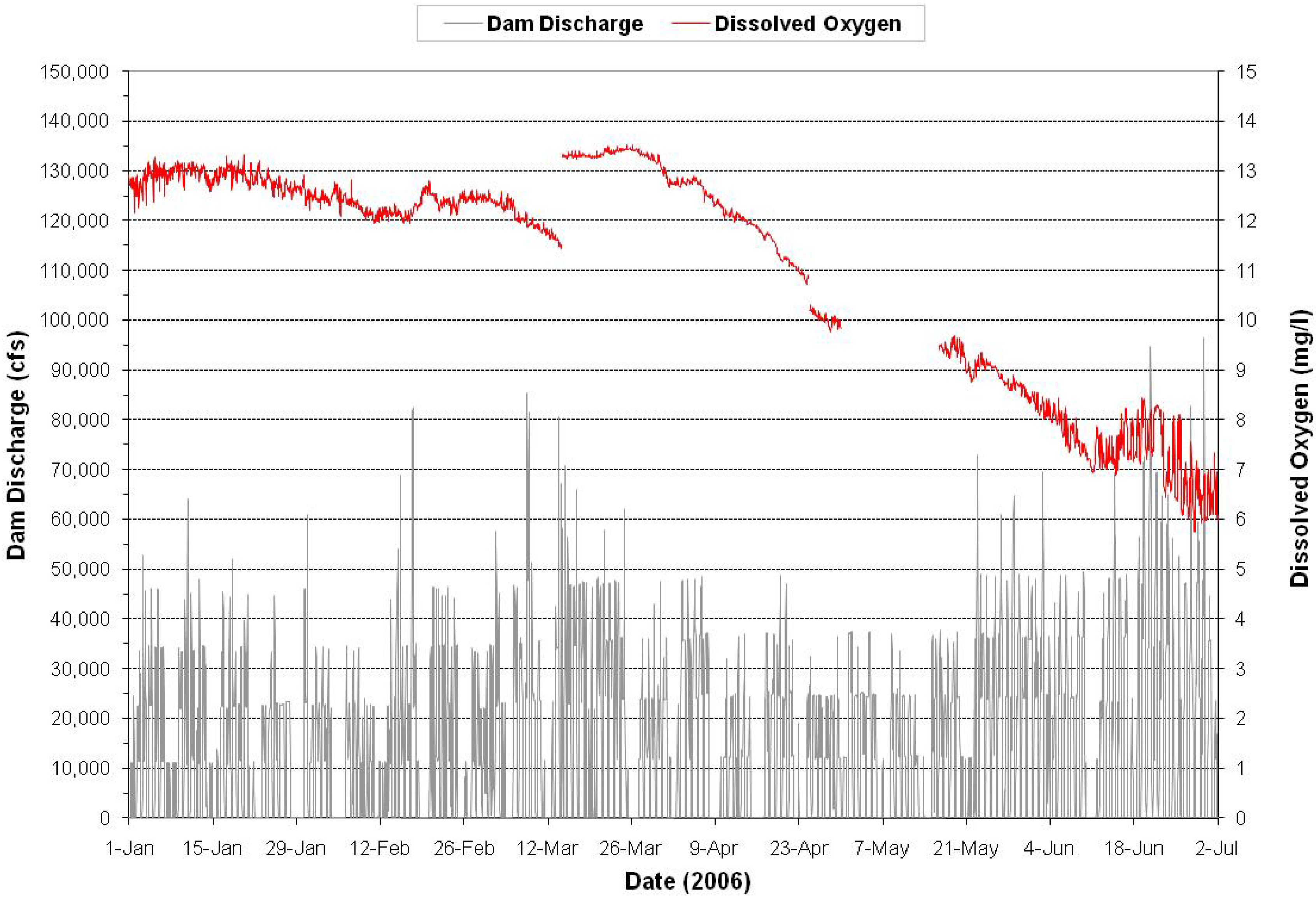

Plate 270. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period January through July 2006.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

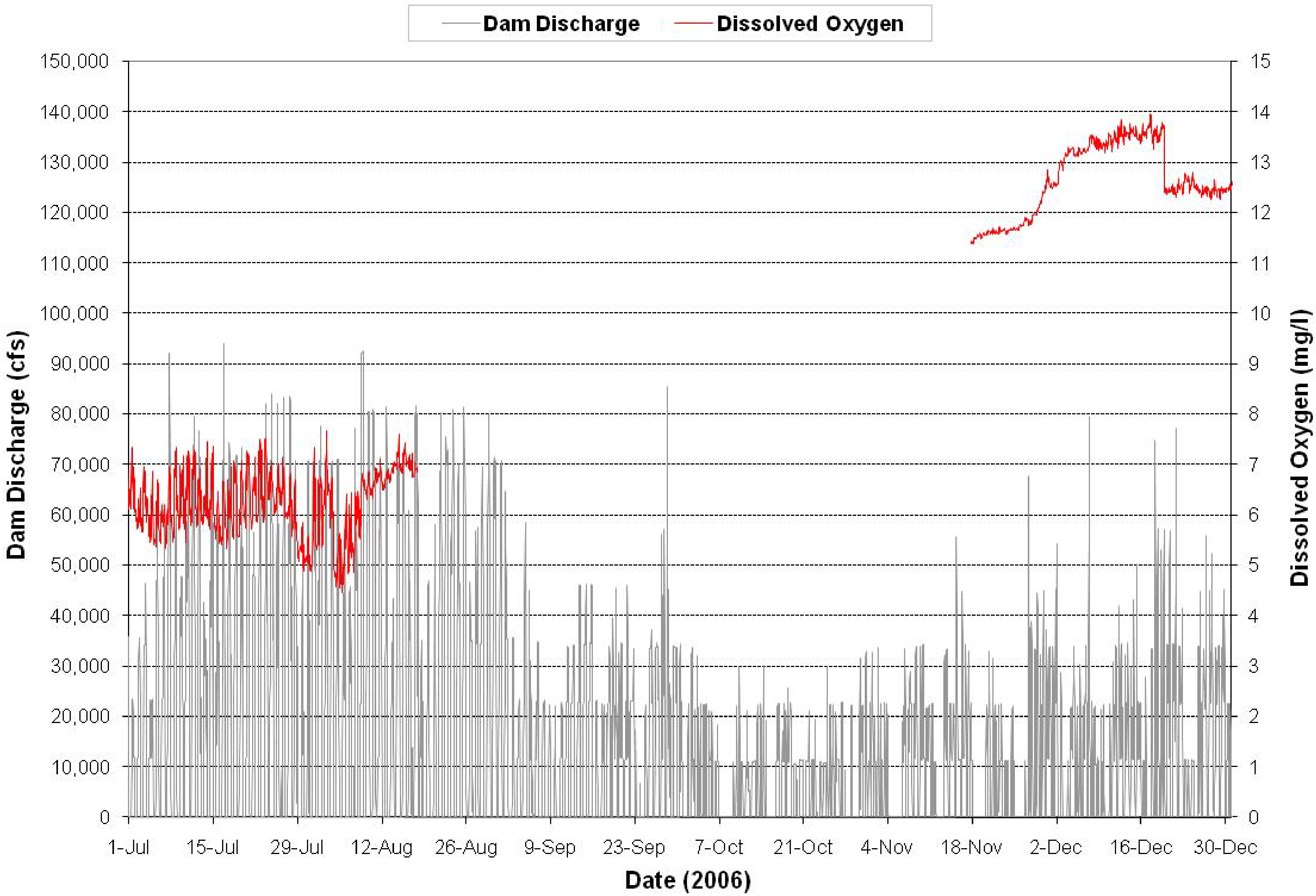

Plate 271. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2006.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

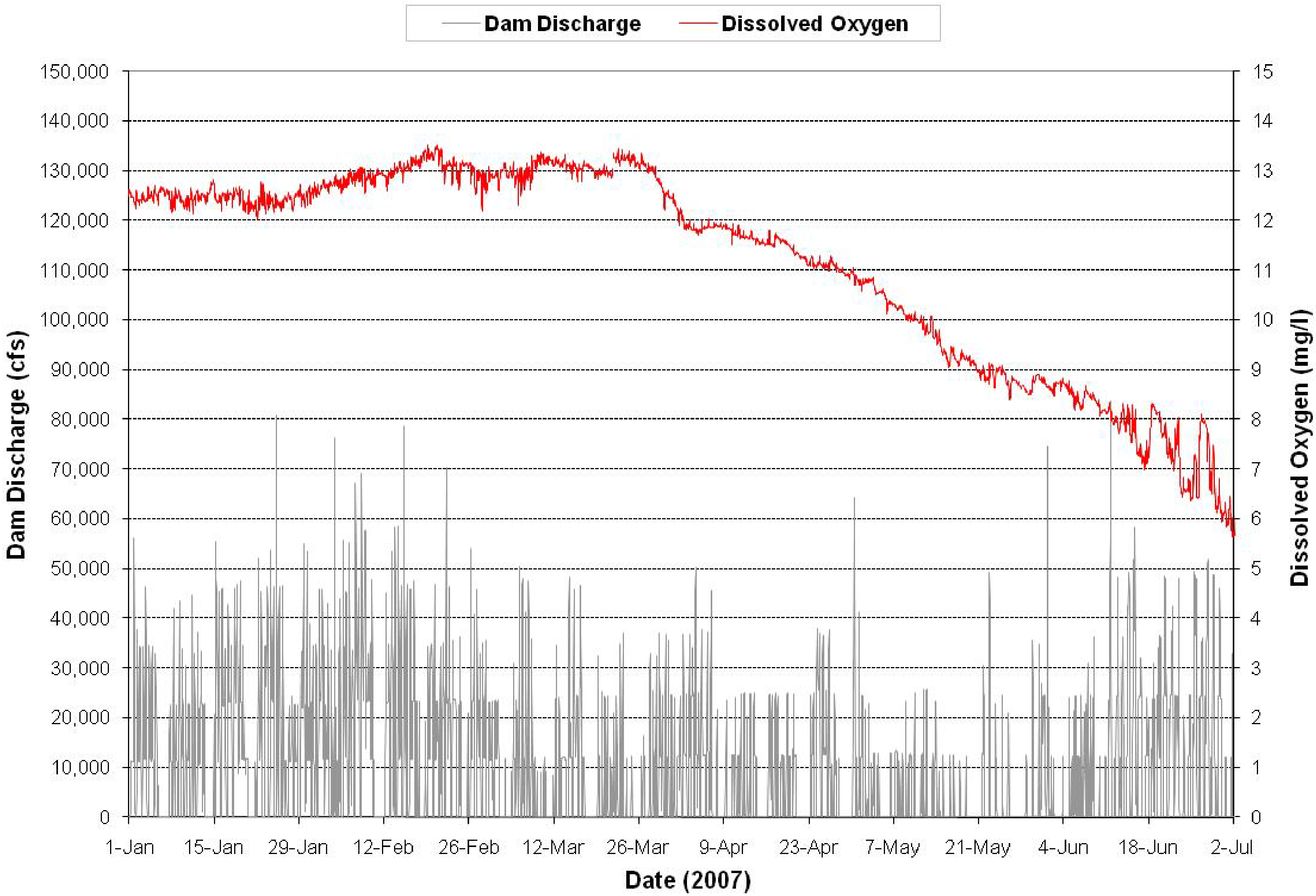

Plate 272. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period January through July 2007.

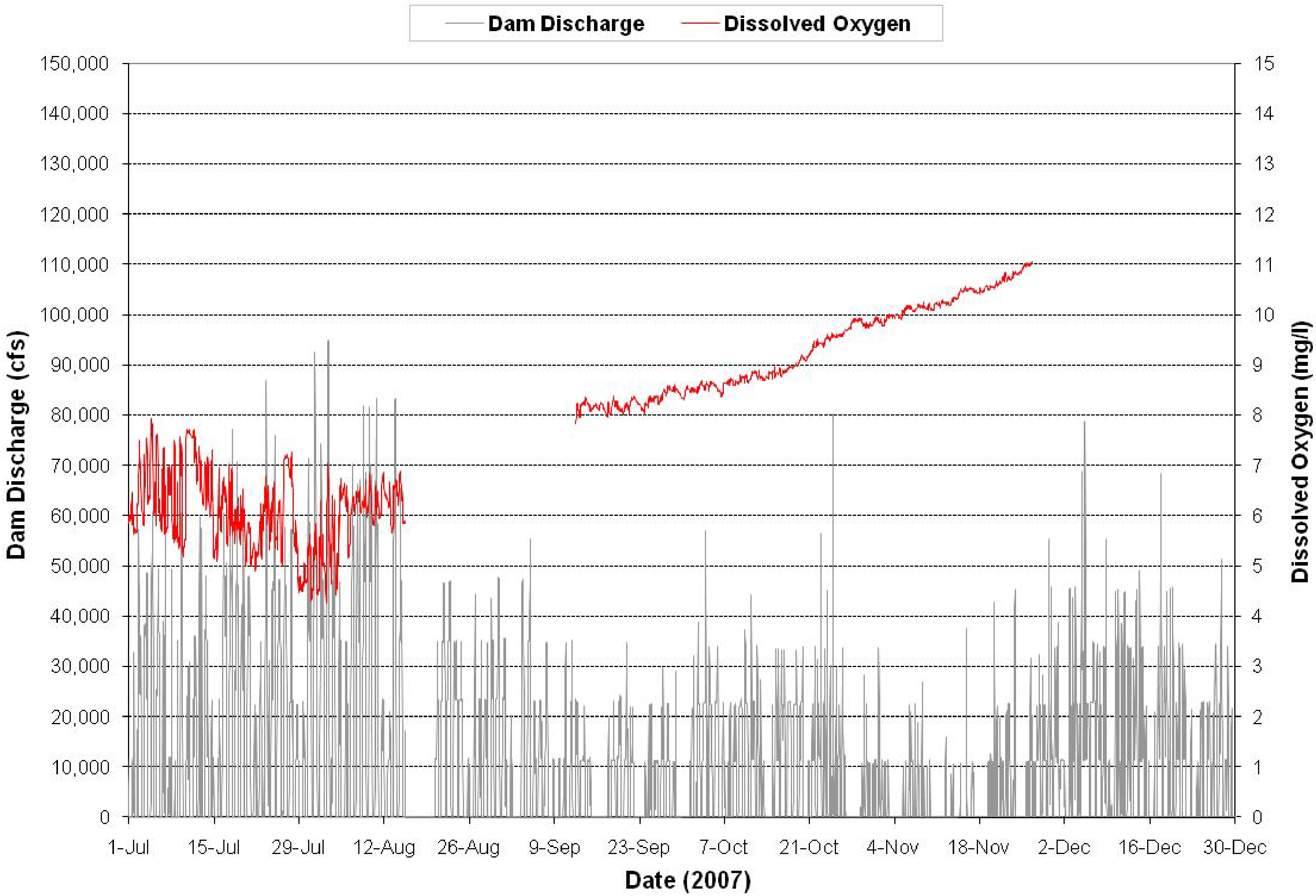

Plate 273. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

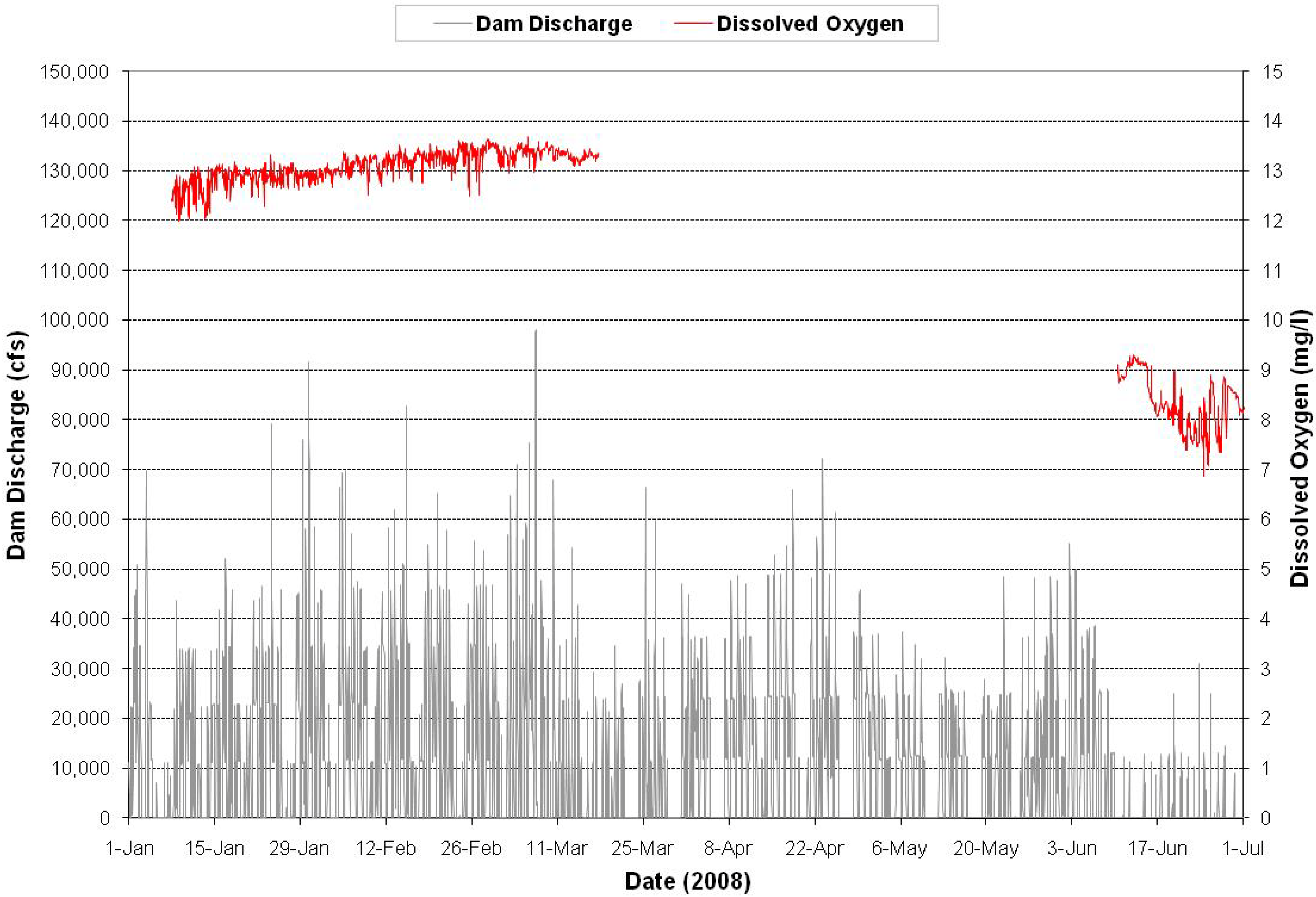

Plate 274. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period January through July 2008.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

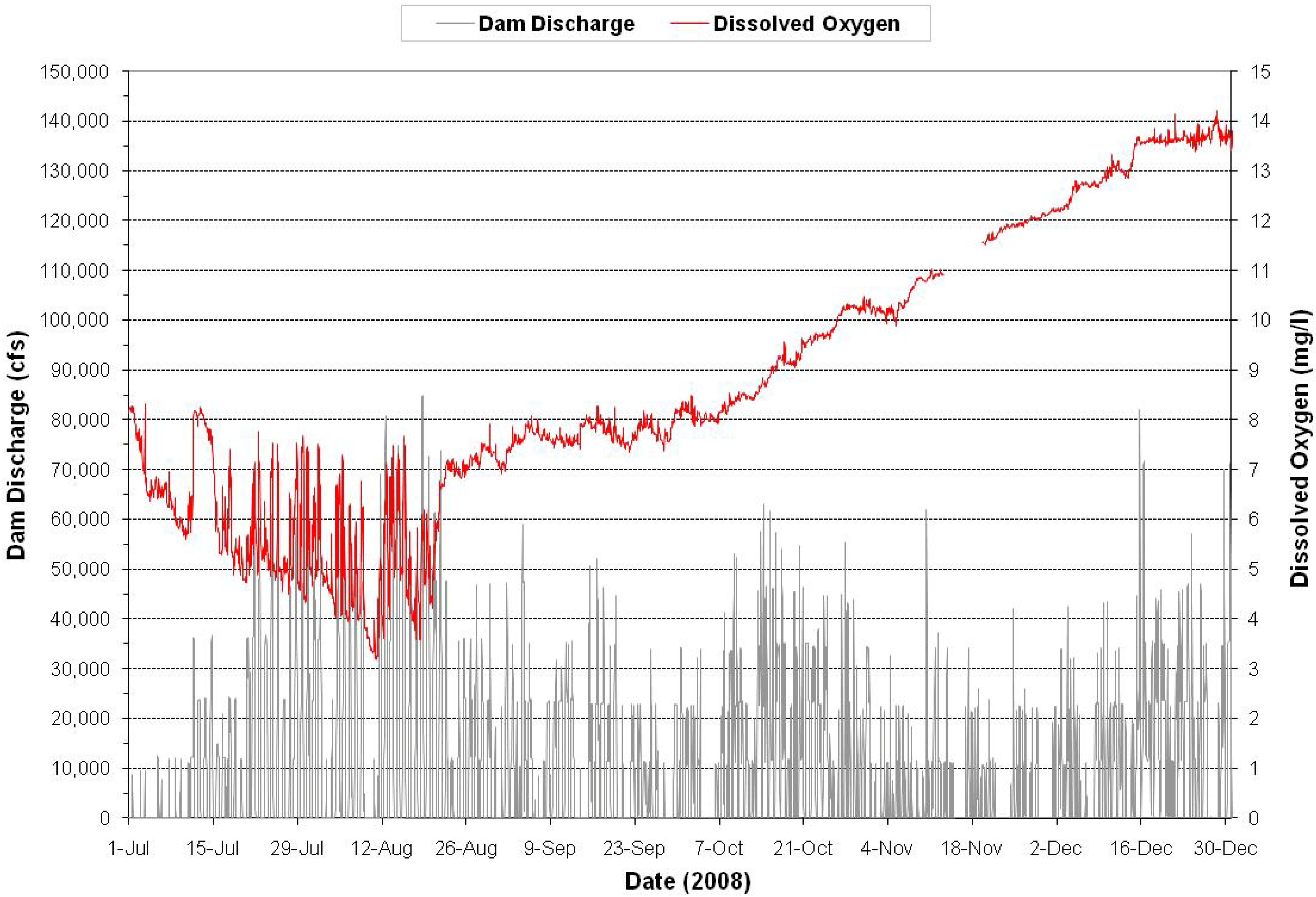

Plate 275. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2008.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

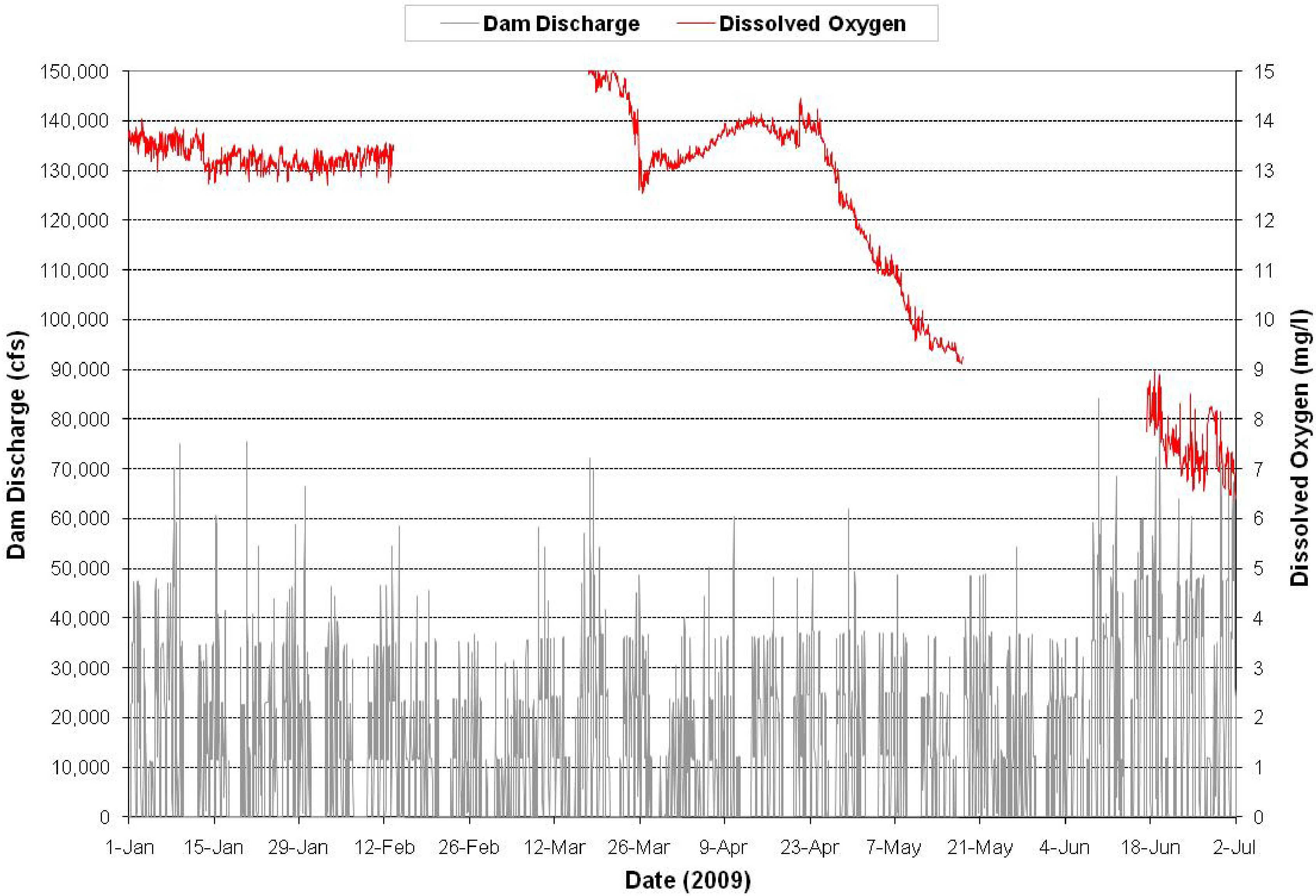

Plate 276. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period January through July 2009.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

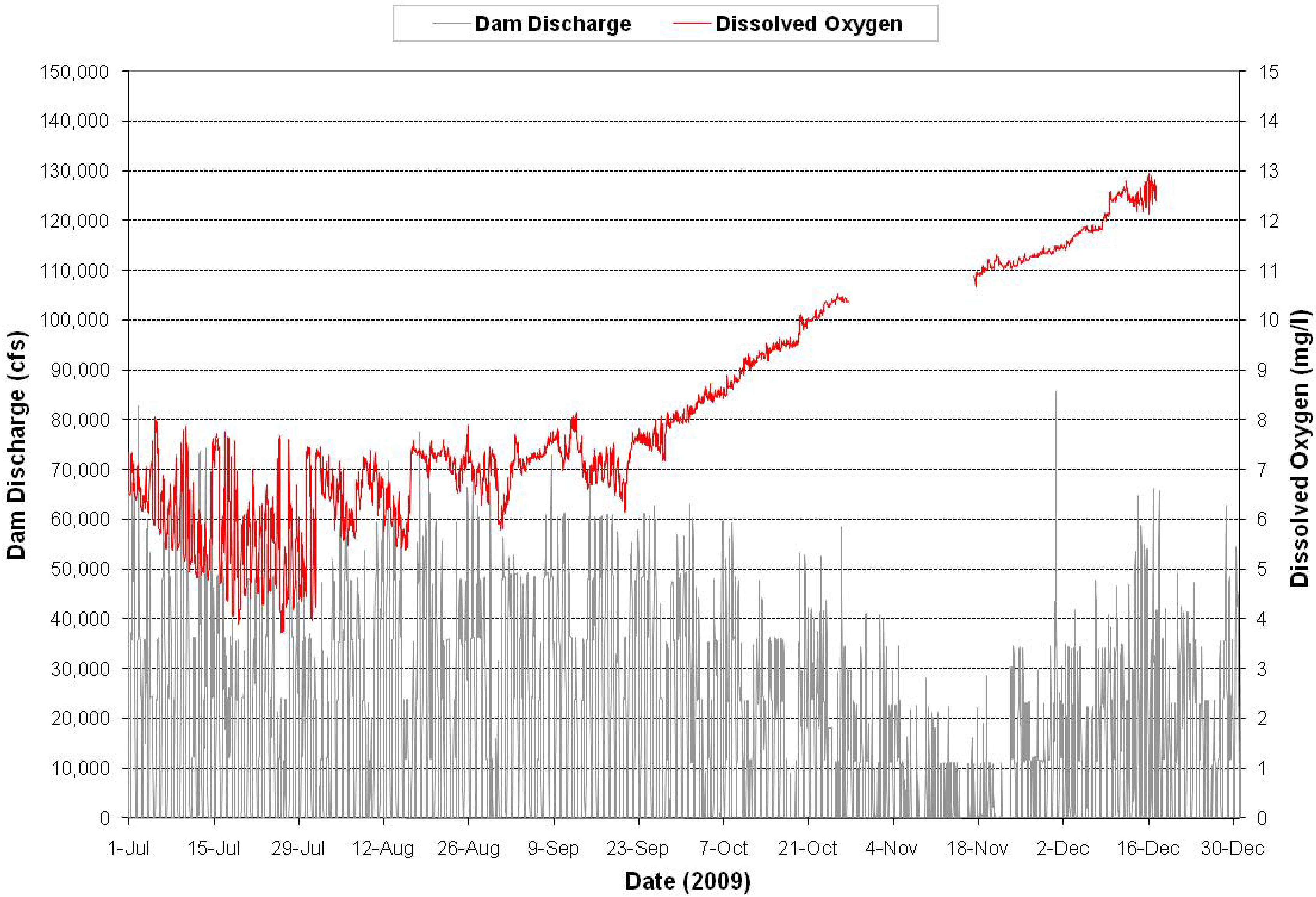

Plate 277. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2009.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

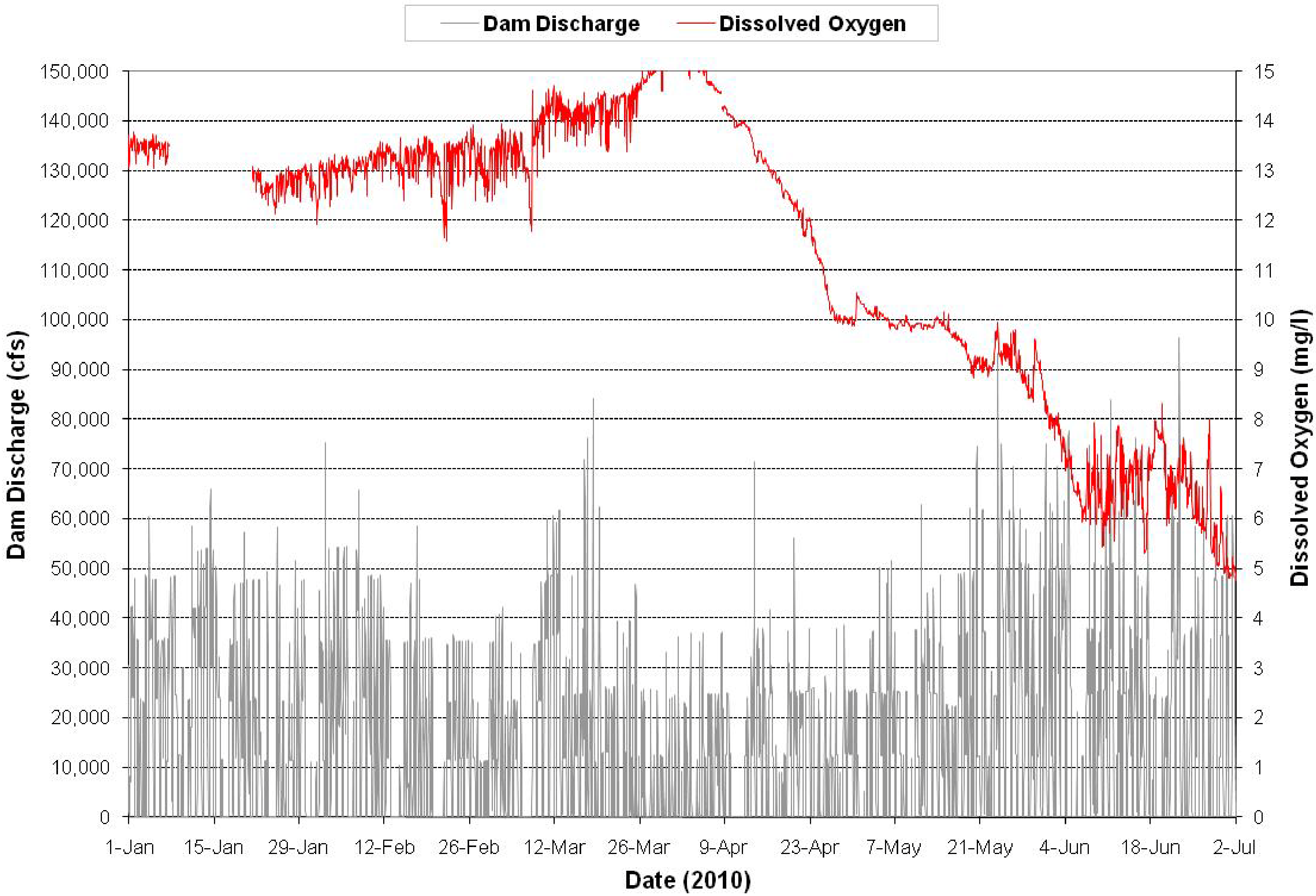

Plate 278. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period January through July 2010.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

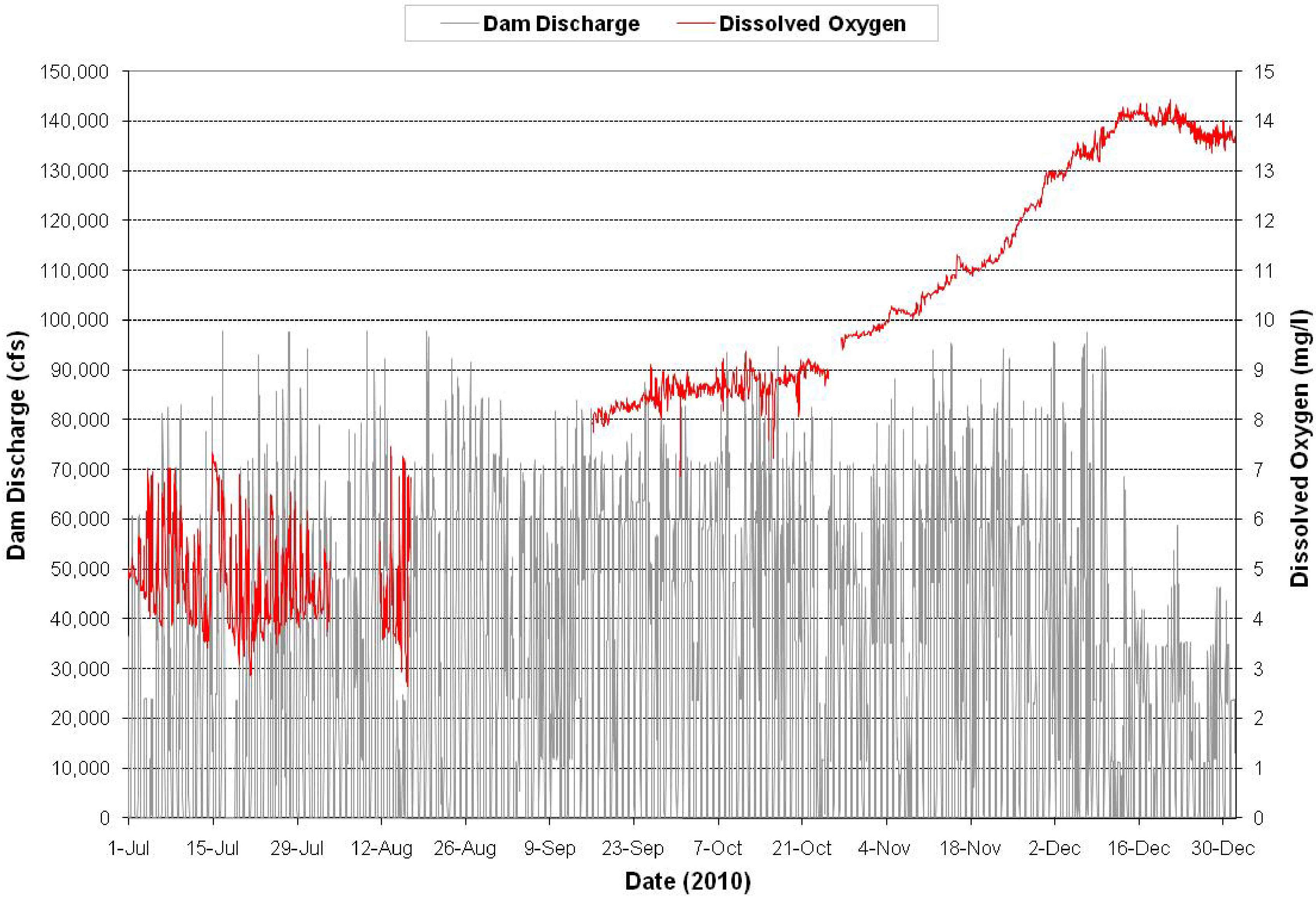

Plate 279. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2010.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

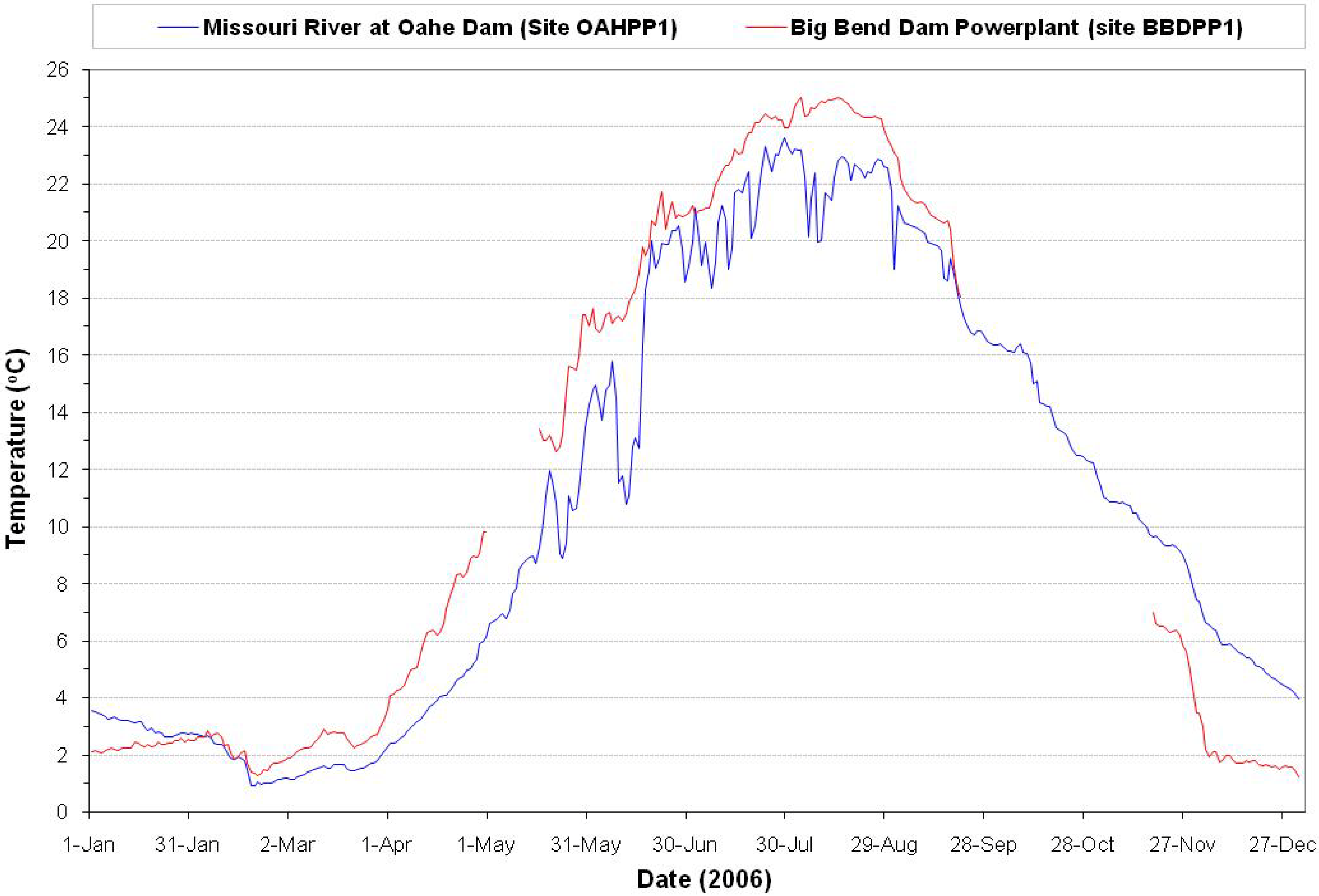

Plate 280. Mean daily water temperatures monitored at the Big Bend Powerplant (i.e., site BBDPP1) and the Missouri River at Oahe Dam (i.e., site OAHPP1) during 2006.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

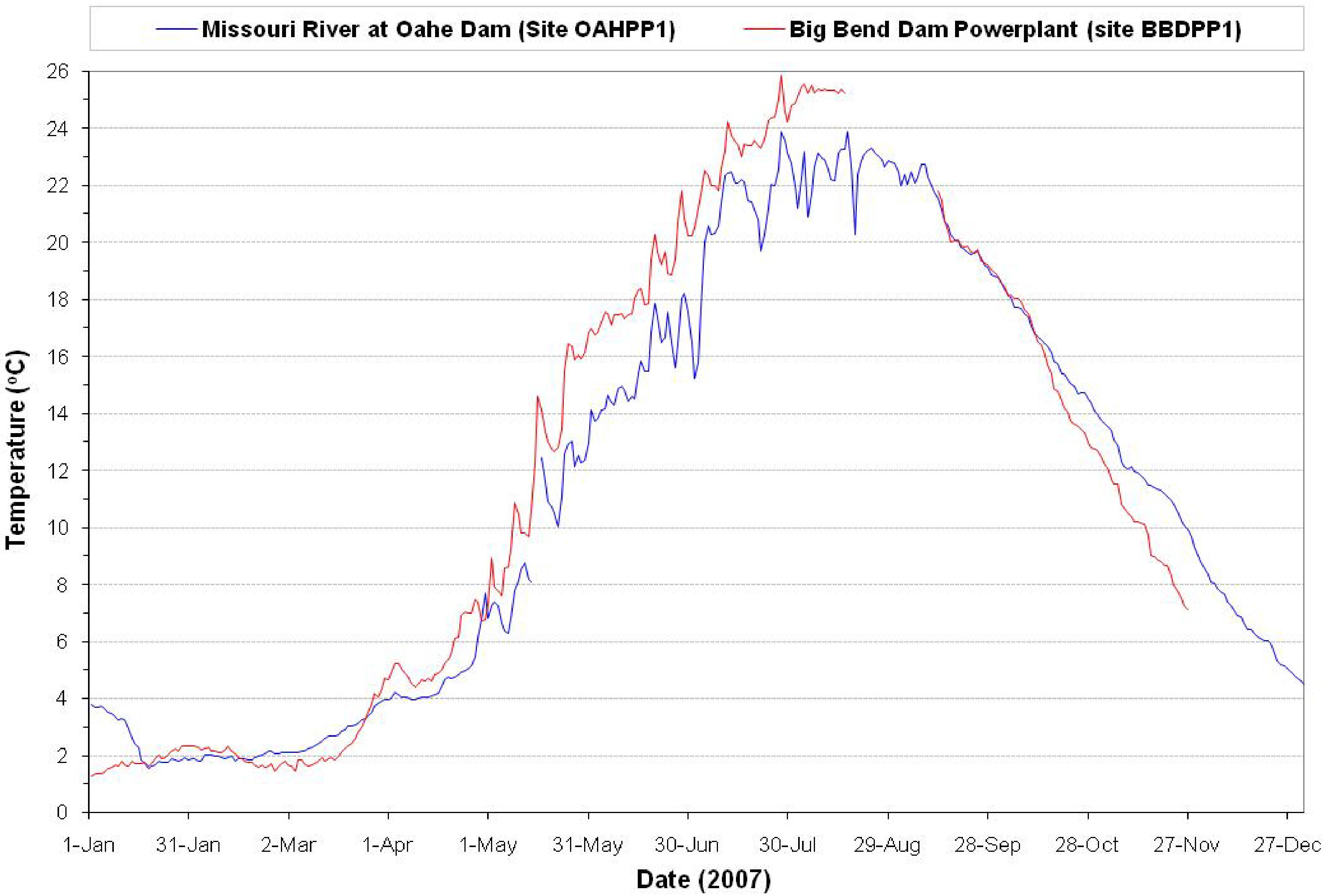

Plate 281. Mean daily water temperatures monitored at the Big Bend Powerplant (i.e., site BBDPP1) and the Missouri River at Oahe Dam (i.e., site OAHPP1) during 2007.
Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

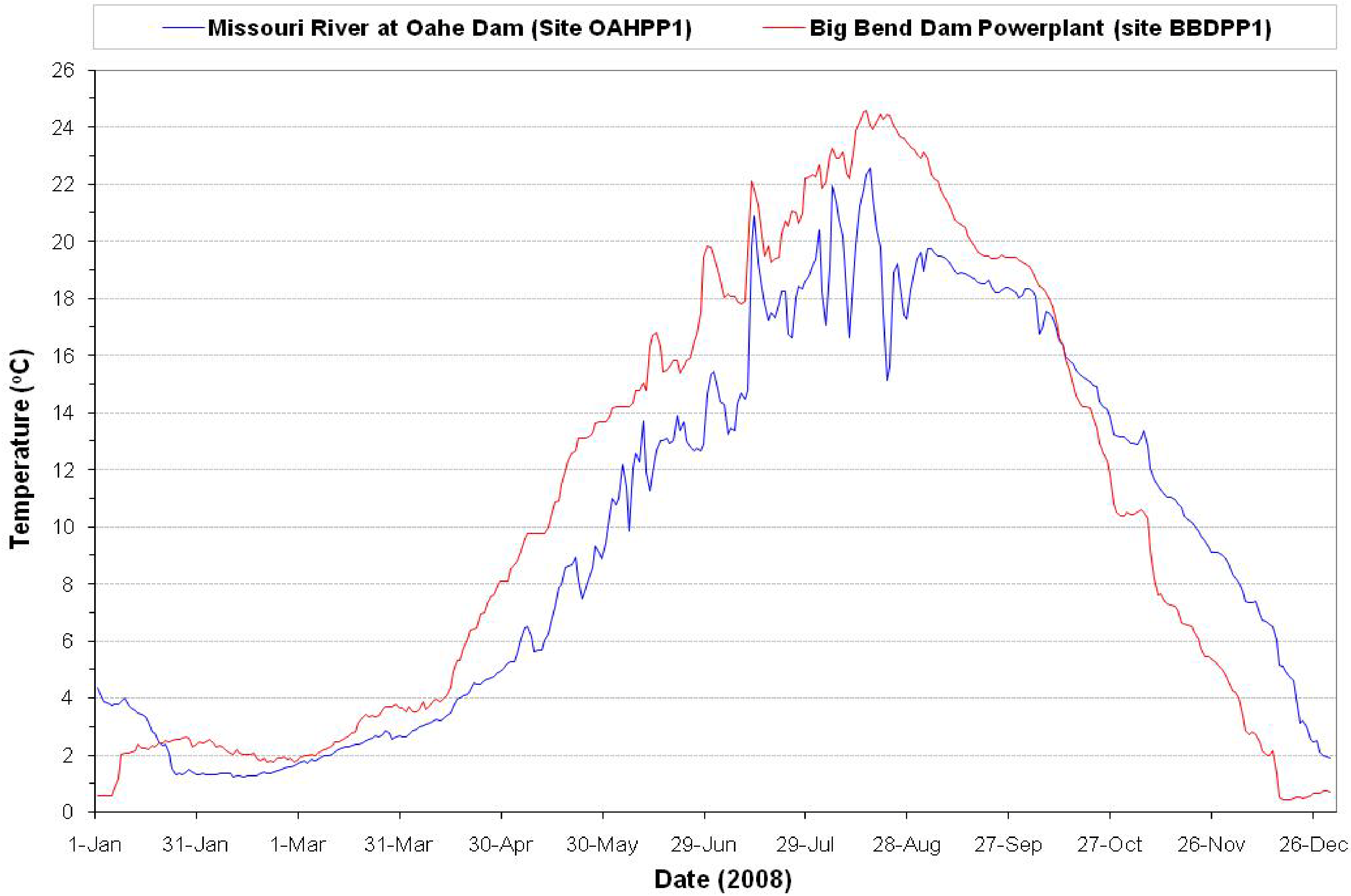

Plate 282. Mean daily water temperatures monitored at the Big Bend Powerplant (i.e., site BBDPP1) and the Missouri River at Oahe Dam (i.e., site OAHPP1) during 2008.

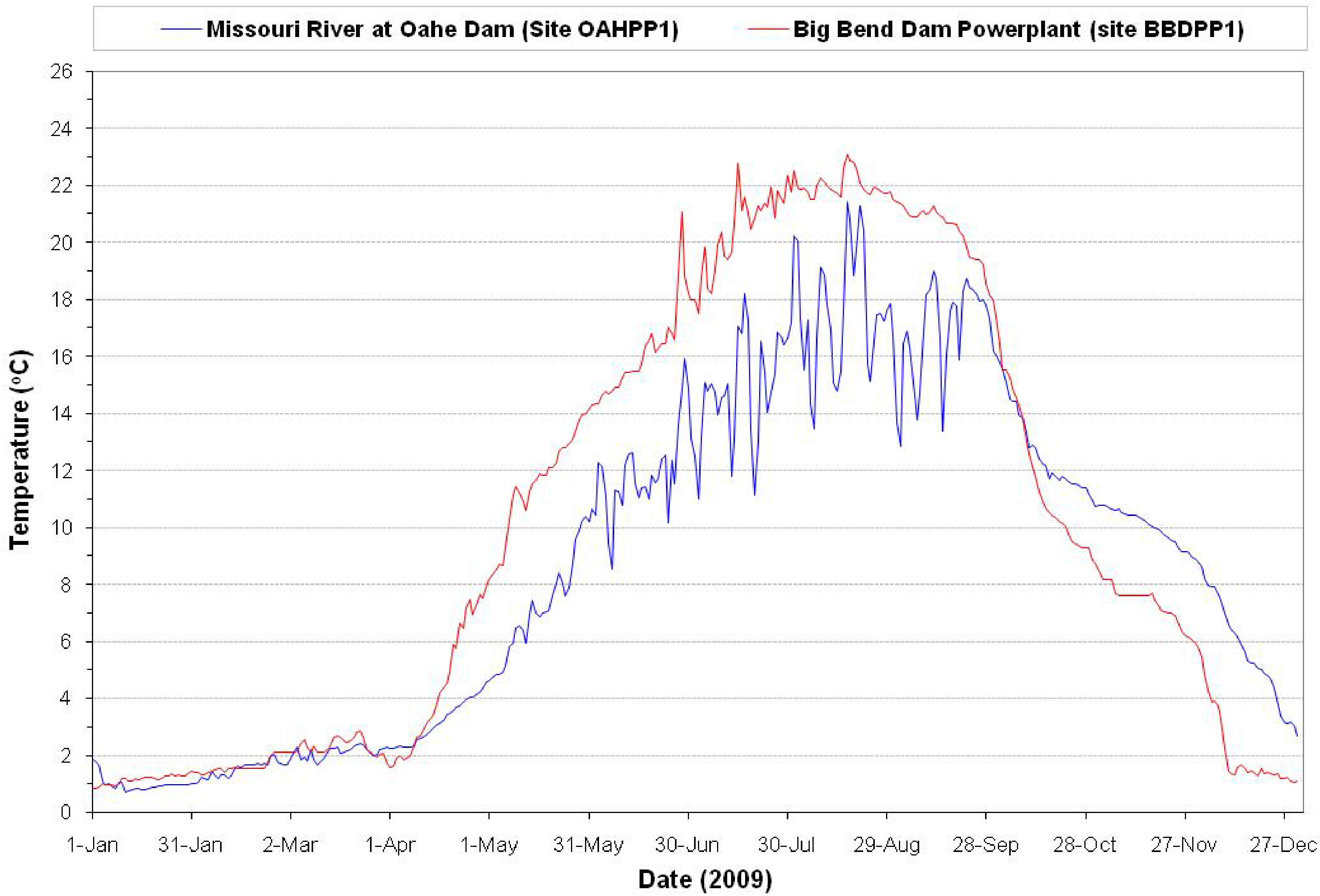

Plate 283. Mean daily water temperatures monitored at the Big Bend Powerplant (i.e., site BBDPP1) and the Missouri River at Oahe Dam (i.e., site OAHPP1) during 2009.

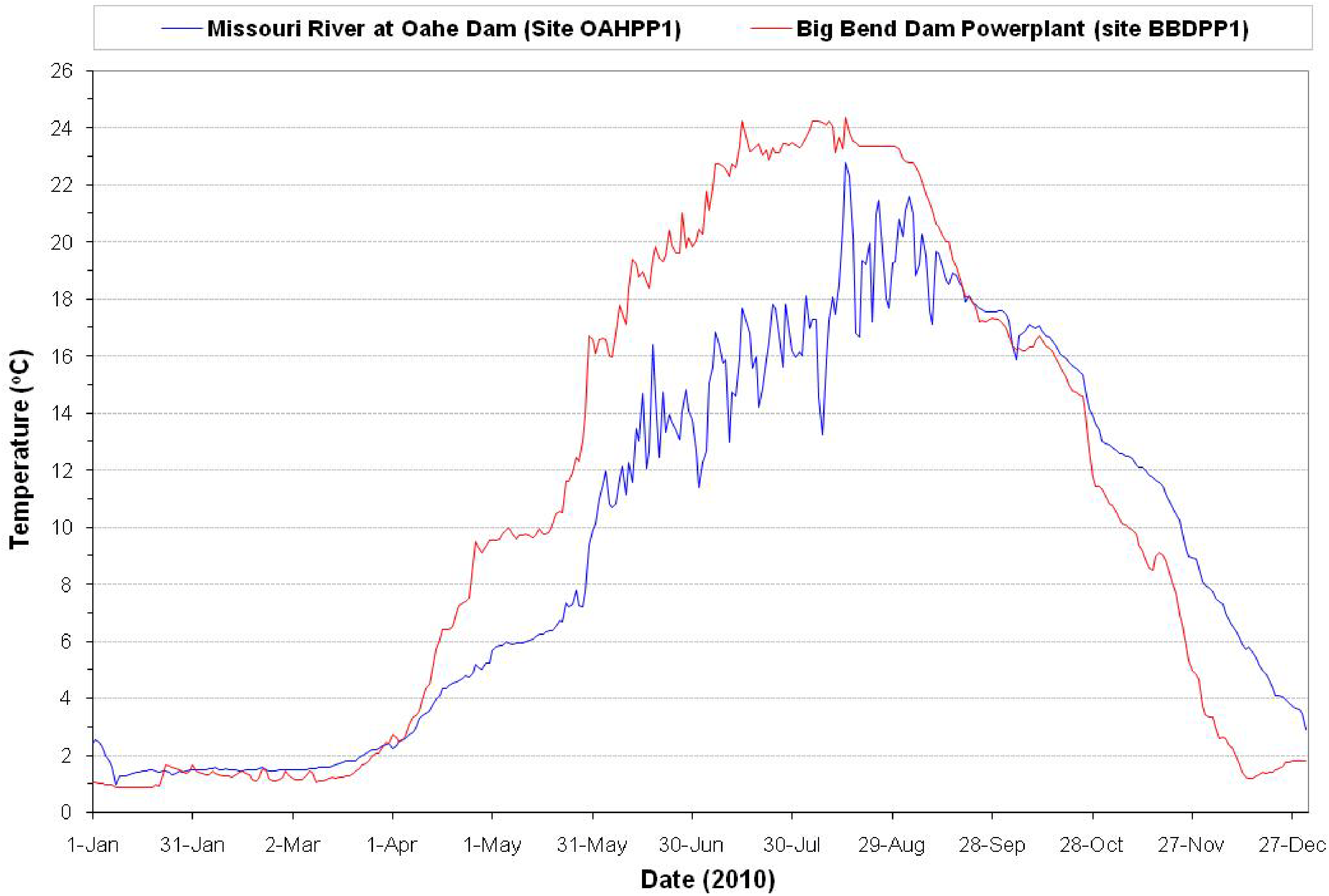

Plate 284. Mean daily water temperatures monitored at the Big Bend Powerplant (i.e., site BBDPP1) and the Missouri River at Oahe Dam (i.e., site OAHPP1) during 2010.

Plate 285. Summary of monthly (May through September) water quality conditions monitored in Lake Francis Case near Fort Randall Dam (Site FTRLK0880A) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	25	1356.2	1355.9	1346.7	1366.5	-----	-----	-----
Water Temperature (°C)	0.1	842	18.4	20.0	6.3	27.0	27[(1,5)]	0	0%
Dissolved Oxygen (mg/l)	0.1	839	8.2	8.0	0.4	11.5	5[(1,6)]	42	5%
Dissolved Oxygen (% Sat.)	0.1	839	89.7	93.6	4.4	107.3	----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	762	8.5	8.0	4.9	11.5	5[(3,6)]	2	<1%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	77	5.6	4.8	0.4	9.9	5[(1,6)]	40	52%
Specific Conductance (umhos/cm)	1	841	728	732	622	770	-----	-----	-----
pH (S.U.)	0.1	809	8.3	8.4	7.2	9.0	6.5[(1,2,6)], 9.0[(1,2,5)], 9.5[(4,5)]	0	0%
Turbidity (NTUs)	1	837	3	2	n.d.	32	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	842	335	333	197	470	-----	-----	-----
Secchi Depth (in.)	1	25	103	92	48	229	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	154	157	127	180	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	46	3.4	3.2	1.6	6.3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	48	11	11	n.d.	21	-----	-----	-----
Chloride (mg/l)	1	38	12	12	10	14	438[(2,5)], 250[(2,7)]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	599	5	4	n.d.	16	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	24	4	3	n.d.	14	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	48	486	479	402	624	1,750[(2,5)], 1,000[(2,7)], 3,500[(4,5)], 2,000[(4,7)]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	48	-----	0.02	n.d.	0.20	2.6 [(1,5,8)], 0.83 [(1,7,8)]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	48	0.6	0.5	n.d.	2.2	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	48	-----	0.02	n.d.	0.60	10[(2,5)]	0	0%
Nitrogen, Total (mg/l)	0.1	48	0.6	0.5	n.d.	2.8	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	48	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	48	0.04	0.03	n.d.	0.25	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	48	-----	n.d.	n.d.	0.07	-----	-----	-----
Sulfate (mg/l)	1	48	212	213	176	233	875[(2,5)], 500[(2,7)]	0	0%
Suspended Solids, Total (mg/l)	4	48	-----	n.d.	n.d.	7	158[(1,5)], 90[(1,7)]	0	0%
Microcystin, Total (ug/l)	0.2	24	-----	n.d.	n.d.	1.8	-----	-----	-----

n.d. = Not detected.

[A] Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

[B] Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

[C] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[D] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

[E] A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

Plate 286. Summary of monthly (June through September) water quality conditions monitored in Lake Francis Case near Pease Creek (site FTRLK0892DW) during the 3-year period 2006 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	12	1354.0	1354.4	1346.7	1362.0	-----	-----	-----
Water Temperature (°C)	0.1	346	21.2	21.4	9.7	26.2	27[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	345	7.7	7.9	1.5	9.8	5[1,6]	19	6%
Dissolved Oxygen (% Sat.)	0.1	345	89.8	93.3	18.0	104.5	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	301	7.9	7.9	5.2	9.8	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	44	6.2	6.9	1.5	9.8	5[1,6]	19	43%
Specific Conductance (umhos/cm)	1	346	728	730	698	740	-----	-----	-----
pH (S.U.)	0.1	317	8.4	8.4	7.7	8.8	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	345	3	2	n.d.	23	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	346	329	320	252	427	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	341	2	1	n.d.	5	-----	-----	-----
Secchi Depth (in)	1	11	107	96	56	194	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. The mean is not reported if 20% or more of the observations were nondetects. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates a significant difference between surface and bottom temperature, and at some point in the measured profile there is at least a 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment

Plate 287. **S**ummary of monthly (June through September) water quality conditions monitored in Lake Francis Case near Platte Creek (Site FTRLK0911DW) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	21	1356.0	1355.2	1346.7	1366.4	-----	-----	-----
Water Temperature (°C)	0.1	520	20.5	21.7	9.1	27.0	27[1,5]	2	<1%
Dissolved Oxygen (mg/l)	0.1	520	7.8	7.9	0.6	10.4	5[1,6]	25	5%
Dissolved Oxygen (% Sat.)	0.1	519	89.1	92.9	7.1	116.8	----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	465	8.0	7.9	1.2	10.4	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	55	5.7	6.4	0.6	9.7	5[1,6]	17	31%
Specific Conductance (umhos/cm)	1	519	732	731	703	779	-----	-----	-----
pH (S.U.)	0.1	495	8.4	8.4	7.4	9.0	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	518	5	43.8	n.d.	32	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	519	327	325	196	425	-----	-----	-----
Secchi Depth (in.)	1	21	78	71	34	148	-----	-----	-----
Alkalinity, Total (mg/l)	7	41	155	154	110	319	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	39	3.4	3.1	2.2	5.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	41	12	13	n.d.	22	-----	-----	-----
Chloride (mg/l)	1	31	12	12	9	14	438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	411	8	5	n.d.	56	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	21	7	5	1	20	-----	-----	-----
Color (APHA)	1	10	10	11	5	14			
Dissolved Solids, Total (mg/l)	4	41	490	480	400	694	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	41	-----	0.02	n.d.	0.33	3.9 [1,5,8], 0.76 [1,7,8]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	41	0.5	0.5	n.d.	1.9	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	41	-----	n.d.	n.d.	0.60	10[2,5]	0	0%
Nitrogen, Total (mg/l)	0.1	41	0.6	0.5	n.d.	2.1	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	41	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	41	-----	0.03	n.d.	0.11	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	41	-----	n.d.	n.d.	0.07	-----	-----	-----
Sulfate (mg/l)	1	41	213	216	180	270	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	41	-----	n.d.	n.d.	15	158[1,5], 90[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	21	-----	n.d.	n.d.	0.3	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

Plate 288. Summary of monthly (June through September) water quality conditions monitored in Lake Francis Case near Snake Creek (site FTRLK0924DW) during the 3-year period 2006 through 2008

	Monitoring Results[A]						Water Quality Standards Attainment		
Parameter	**Detection Limit[B]**	**No. of Obs.**	**Mean[C]**	**Median**	**Min.**	**Max.**	**State WQS Criteria[D]**	**No. of WQS Exceedances**	**Percent WQS Exceedance**
Pool Elevation (ft-NGVD29)	0.1	12	1354.0	1354.4	1347.1	1362.0	-----	-----	-----
Water Temperature (°C)	0.1	214	22.2	22.9	11.6	27.2	27(1,5)	1	<1%
Dissolved Oxygen (mg/l)	0.1	214	7.9	7.9	3.2	9.5	5(1,6)	19	6%
Dissolved Oxygen (% Sat.)	0.1	214	93.7	94.7	39.4	114.4	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	199	7.9	7.9	6.2	9.5	5(3,6)	1	<1%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	15	7.2	6.7	3.2	9.2	5(1,6)	1	7%
Specific Conductance (umhos/cm)	1	214	721	720	693	738	-----	-----	-----
pH (S.U.)	0.1	196	8.4	8.5	7.8	8.6	6.5(1,2,6), 9.0(1,2,5), 9.5(4,5)	0	0%
Turbidity (NTUs)	1	213	9	8	2	58	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	214	330	314	255	498	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	211	3	2	n.d.	21	-----	-----	-----
Secchi Depth (in)	1	12	47	47	25	84	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. The mean is not reported if 20% or more of the observations were nondetects. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment

Plate 289. Summary of monthly (June through September) water quality conditions monitored in Lake Francis Case near Elm Creek (Site FTRLK0940DW) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results(A)						Water Quality Standards Attainment		
	Detection Limit(B)	No. of Obs.	Mean(C)	Median	Min.	Max.	State WQS Criteria(D)	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	18	1356.2	1355.4	1347.1	1364.2	-----	-----	-----
Water Temperature (°C)	0.1	108	22.0	23.6	13.8	27.1	27(1,5)	7	6%
Dissolved Oxygen (mg/l)	0.1	108	8.8	8.5	7.6	13.5	5(1,6)	0	0%
Dissolved Oxygen (% Sat.)	0.1	108	104.4	101.4	92.1	141.7	----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)(E)	0.1	108	8.8	8.5	7.6	13.5	5(3,6)	0	0%
Hypolimnion Dissolved Oxygen (mg/l)(E)	0.1	0	-----	-----	-----	-----	5(1,6)	-----	-----
Specific Conductance (umhos/cm)	1	108	725	726	659	793	-----	-----	-----
pH (S.U.)	0.1	102	8.5	8.5	8.1	8.8	6.5(1,2,6), 9.0(1,2,5), 9.5(4,5)	0	0%
Turbidity (NTUs)	1	108	19	11	n.d.	284	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	108	340	328	265	462	-----	-----	-----
Secchi Depth (in.)	1	17	28	24	7	52	-----	-----	-----
Alkalinity, Total (mg/l)	7	35	152	153	126	170	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	33	3.4	3.3	1.7	5.4	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	34	13	14	4	30	-----	-----	-----
Chloride (mg/l)	1	29	11	12	9	14	438(2,5), 250(2,7)	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	87	14	8	3	56	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	18	9	8	n.d.	30	-----	-----	-----
Color (APHA)	1	6	11	8	6	21			
Dissolved Solids, Total (mg/l)	4	35	481	480	392	698	1,750(2,5), 1,000(2,7), 3,500(4,5), 2,000(4,7)	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	35	-----	n.d.	n.d.	0.24	3.5 (1,5,8), 0.63 (1,7,8)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	35	0.7	0.6	n.d.	2.4	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	35	-----	n.d.	n.d.	0.30	10(2,5)	0	0%
Nitrogen, Total (mg/l)	0.1	35	0.7	0.7	n.d.	2.4	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	35	-----	n.d.	n.d.	0.05	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	35	0.04	0.04	n.d.	0.13	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	35	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	35	208	209	176	241	875(2,5), 500(2,7)	0	0%
Suspended Solids, Total (mg/l)	4	34	18	8	n.d.	140	158(1,5), 90(1,7)	0, 2	0%, 6%
Microcystin, Total (ug/l)	0.2	18	-----	n.d.	n.d.	0.2	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

Plate 290. Summary of monthly (June through September) water quality conditions monitored in Lake Francis Case near the White River (site FTRLK0955DW) during the 3-year period 2006 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	12	1354.0	1354.3	1347.1	1361.6	-----	-----	-----
Water Temperature (°C)	0.1	50	22.6	24.4	14.9	26.0	27[(1,5)]	0	0%
Dissolved Oxygen (mg/l)	0.1	49	8.1	8.1	0.1	9.5	5[(1,6)]	19	6%
Dissolved Oxygen (% Sat.)	0.1	49	96.9	100.8	1.6	104.1	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	49	8.1	8.1	0.1	9.5	5[(3,6)]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0[F]	-----	-----	-----	-----	5[(1,6)]	-----	-----
Specific Conductance (umhos/cm)	1	50	706	704	559	735	-----	-----	-----
pH (S.U.)	0.1	45	8.4	8.5	8.0	8.7	6.5[(1,2,6)], 9.0[(1,2,5)], 9.5[(4,5)]	0	0%
Turbidity (NTUs)	1	47	33	20	8	210	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	50	354	311	250	614	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	49	5	4	n.d.	12	-----	-----	-----
Secchi Depth (in)	1	11	20	18	11	32	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. The mean is not reported if 20% or more of the observations were nondetects. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

Plate 291. **S**ummary of monthly (June through September) water quality conditions monitored in Lake Francis Case near Chamberlain, SD (Site FTRLK0968DW) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	22	1355.9	1355.2	1347.1	1366.3	-----	-----	-----
Water Temperature (°C)	0.1	149	21.1	21.9	12.1	28.3	27[1,5]	1	1%
Dissolved Oxygen (mg/l)	0.1	149	8.6	8.5	7.3	12.5	5[1,6]	0	0%
Dissolved Oxygen (% Sat.)	0.1	149	100.1	99.2	91.2	125.5	----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	149	8.6	8.5	7.3	12.5	5[1,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0	-----	-----	-----	-----	5[1,6]	-----	-----
Specific Conductance (umhos/cm)	1	149	721	722	657	789	-----	-----	-----
pH (S.U.)	0.1	143	8.5	8.4	8.1	9.0	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	149	16	16	6	40	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	149	346	319	198	545	-----	-----	-----
Secchi Depth (in.)	1	21	24	24	14	34	-----	-----	-----
Alkalinity, Total (mg/l)	7	34	155	158	118	170	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	32	3.1	3.0	1.5	5.3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	34	11	11	n.d.	20	-----	-----	-----
Chloride (mg/l)	1	29	11	11	9	14	438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	122	13	9	3	51	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	22	10	8	n.d.	34	-----	-----	-----
Color (APHA)	1	5	10	7	5	19	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	34	492	488	382	592	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	34	-----	n.d.	n.d.	0.22	3.9 [1,5,8], 0.76 [1,7,8]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	34	0.6	0.5	n.d.	2.5	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	34	-----	n.d.	n.d.	0.80	10[2,5]	0	0%
Nitrogen, Total (mg/l)	0.1	34	0.6	0.5	n.d.	2.5	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	34	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	37	0.06	0.05	n.d.	0.31	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	34	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	34	205	208	173	238	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	33	13	12	5	28	158[1,5], 90[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	22	-----	n.d.	n.d.	0.3	-----	-----	-----

n.d. = Not detected.

[A] Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

[B] Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

[C] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

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- [4] Criteria for the protection of commerce and industry waters.
- [5] Daily maximum criterion (monitoring results directly comparable to criterion).
- [6] Daily minimum criterion (monitoring results directly comparable to criterion).
- [7] 30-day average criterion (monitoring results not directly comparable to criterion).
- [8] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

[E] A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

[F] Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

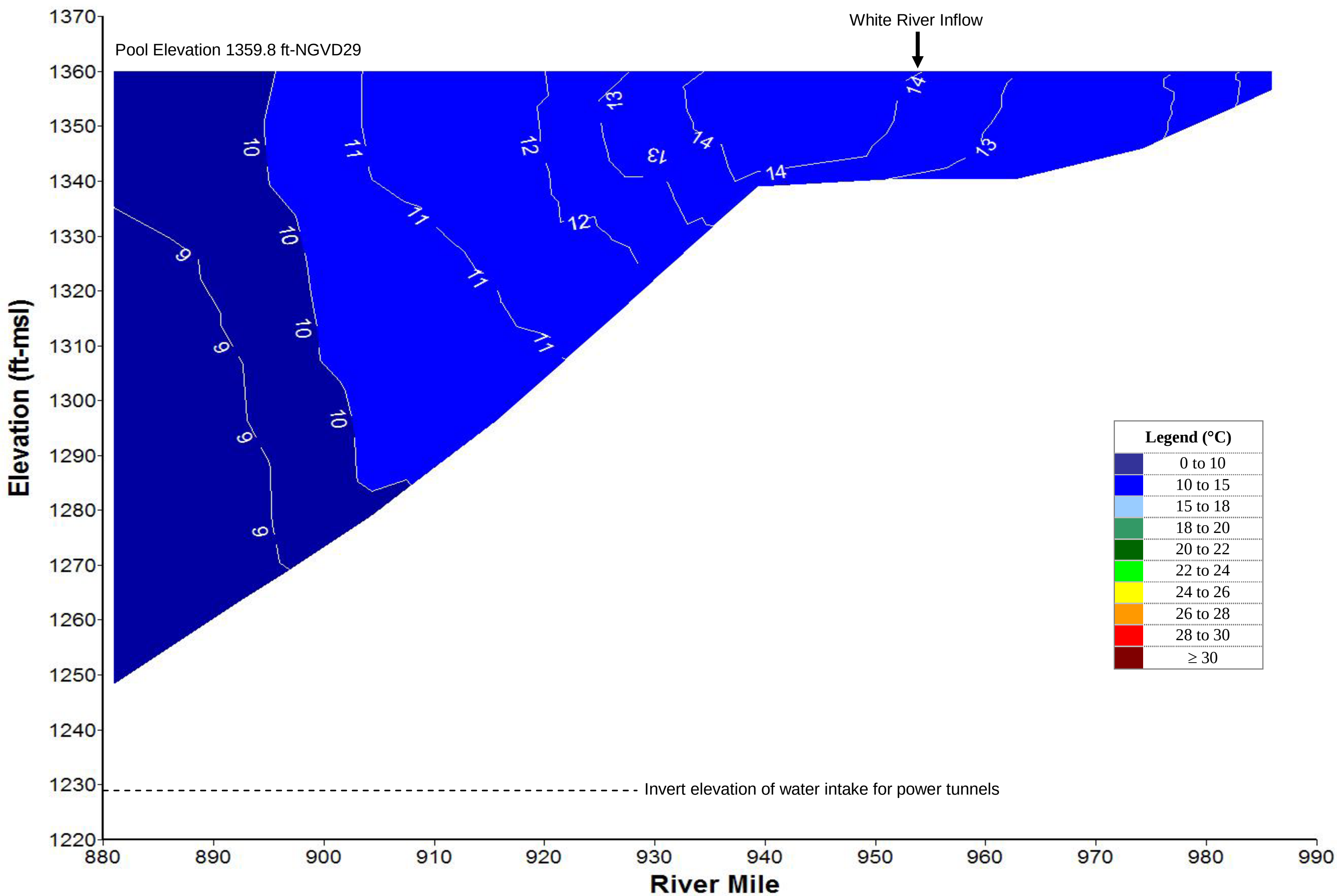

Plate 292. Longitudinal water temperature (°C) contour plot of Lake Francis Case based on depth-profile water temperatures measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on May 19, 2010.

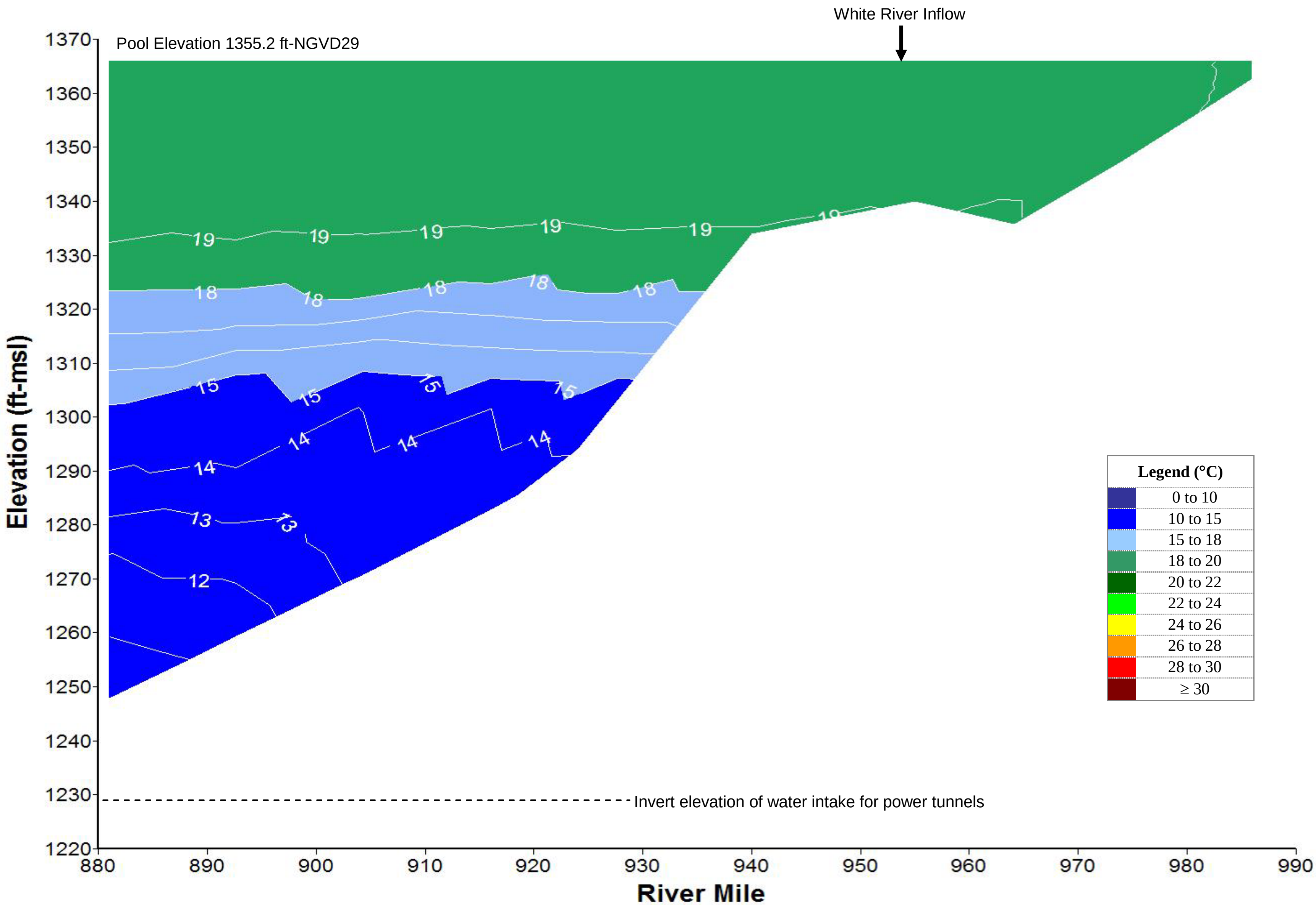

Plate 293. Longitudinal water temperature (°C) contour plot of Lake Francis Case based on depth-profile water temperatures measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0968DW, and BBDPP1 on June 17, 2010.

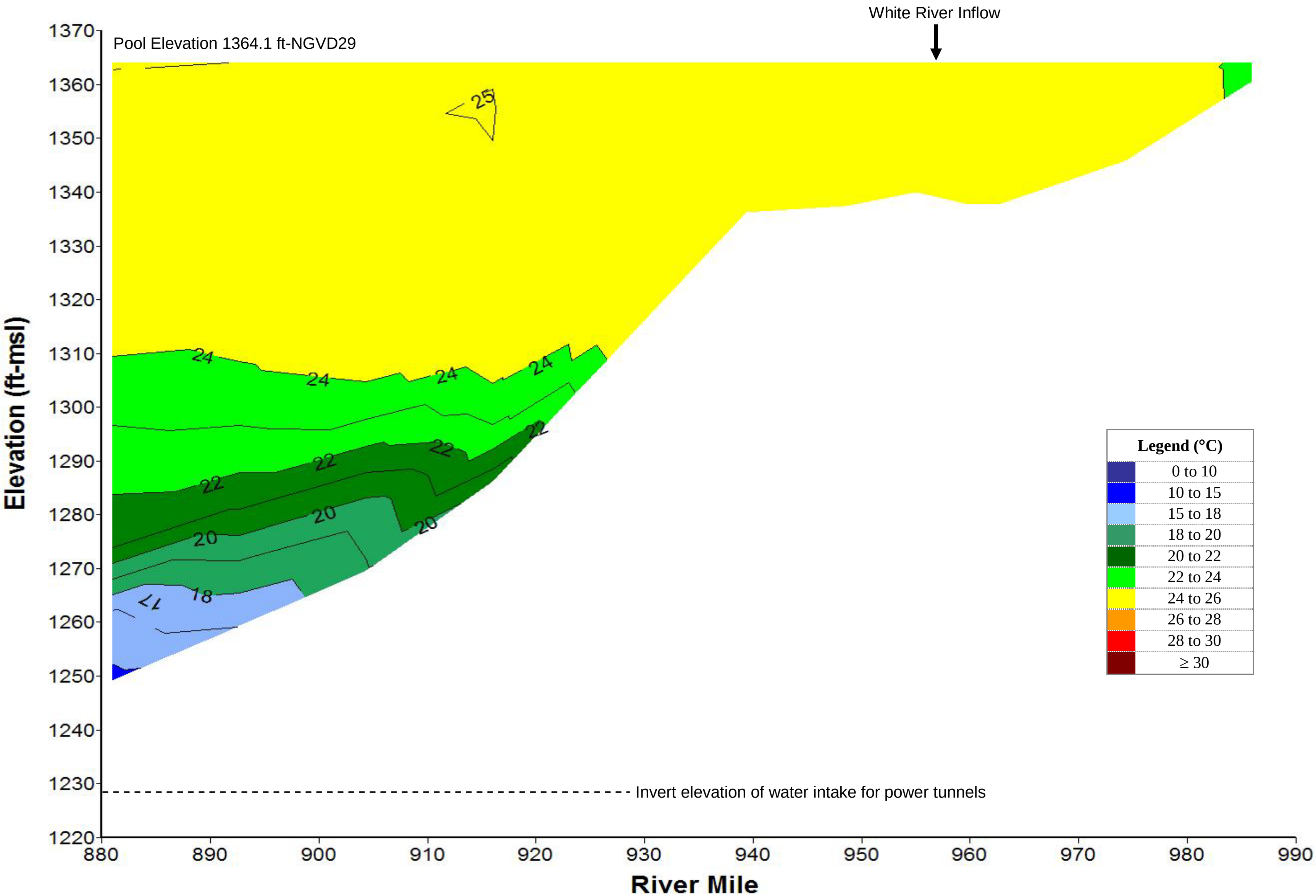

Plate 294. Longitudinal water temperature (°C) contour plot of Lake Francis Case based on depth-profile water temperatures measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on July 15, 2010.

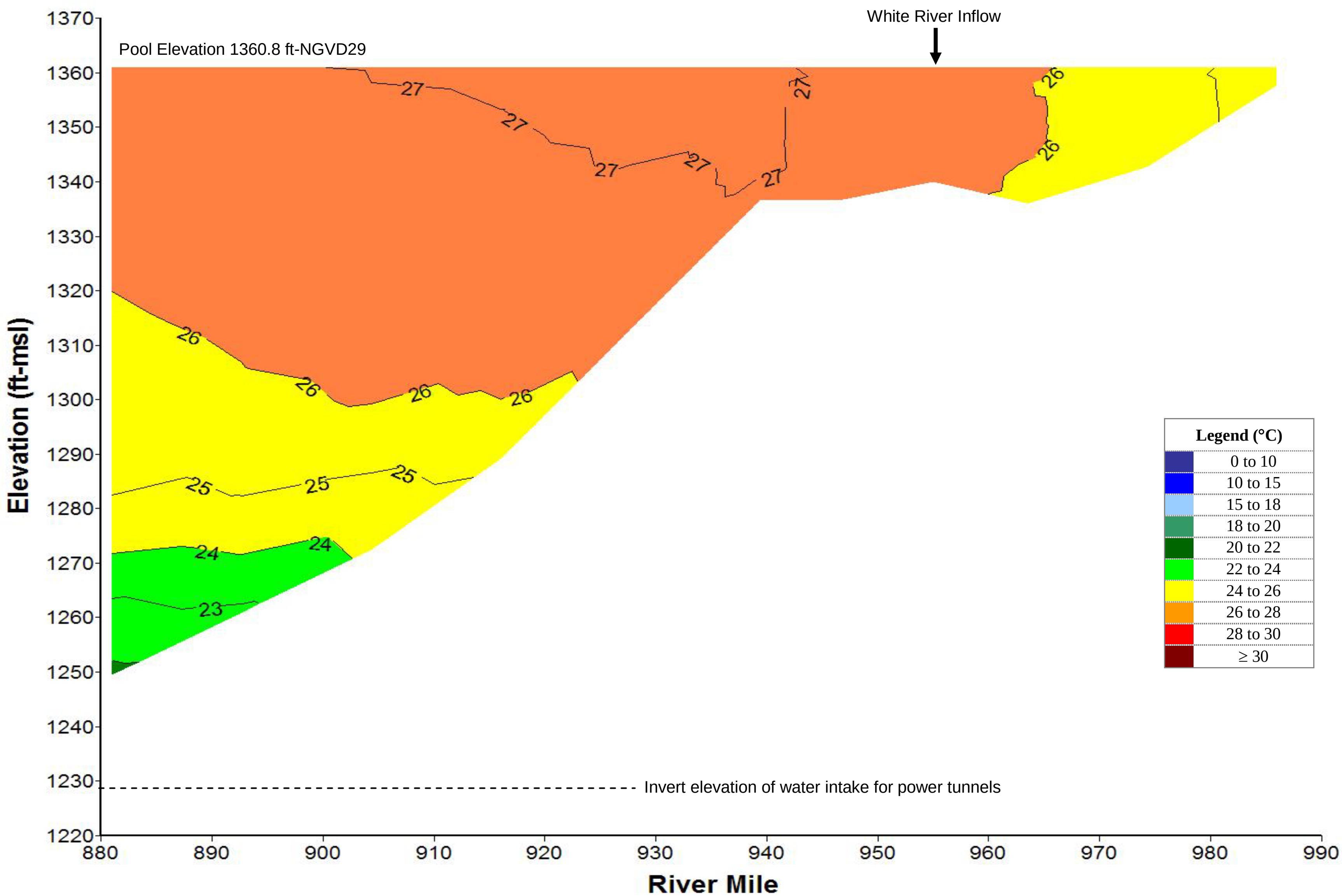

Plate 295. Longitudinal water temperature (°C) contour plot of Lake Francis Case based on depth-profile water temperatures measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on August 12, 2010.

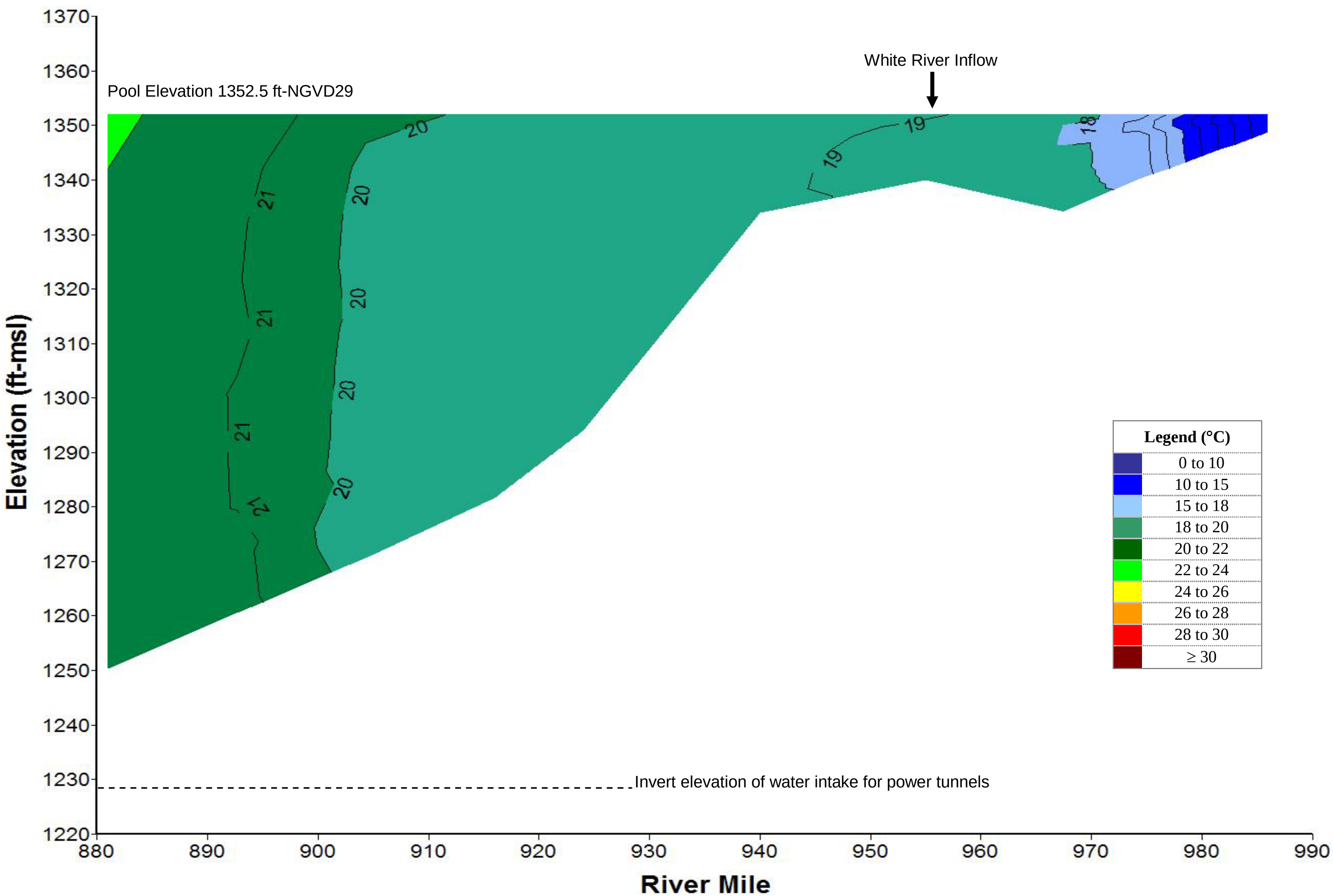

Plate 296. Longitudinal water temperature (°C) contour plot of Lake Francis Case based on depth-profile water temperatures measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on September 16, 2010.

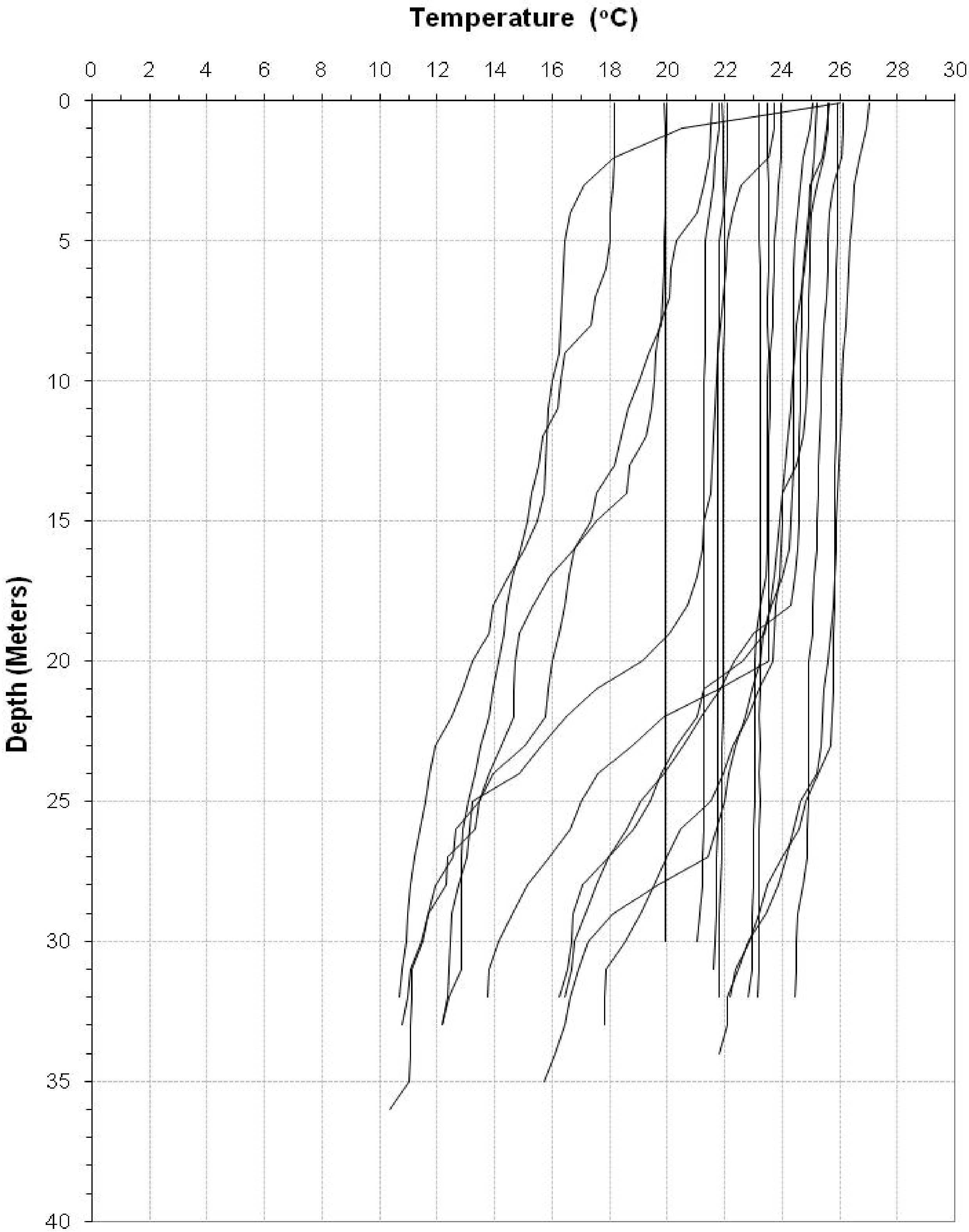

Plate 297. Temperature depth profiles for Lake Francis Case generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., site FTRLK0880A) during the summer months over the 5-year period of 2006 to 2010.

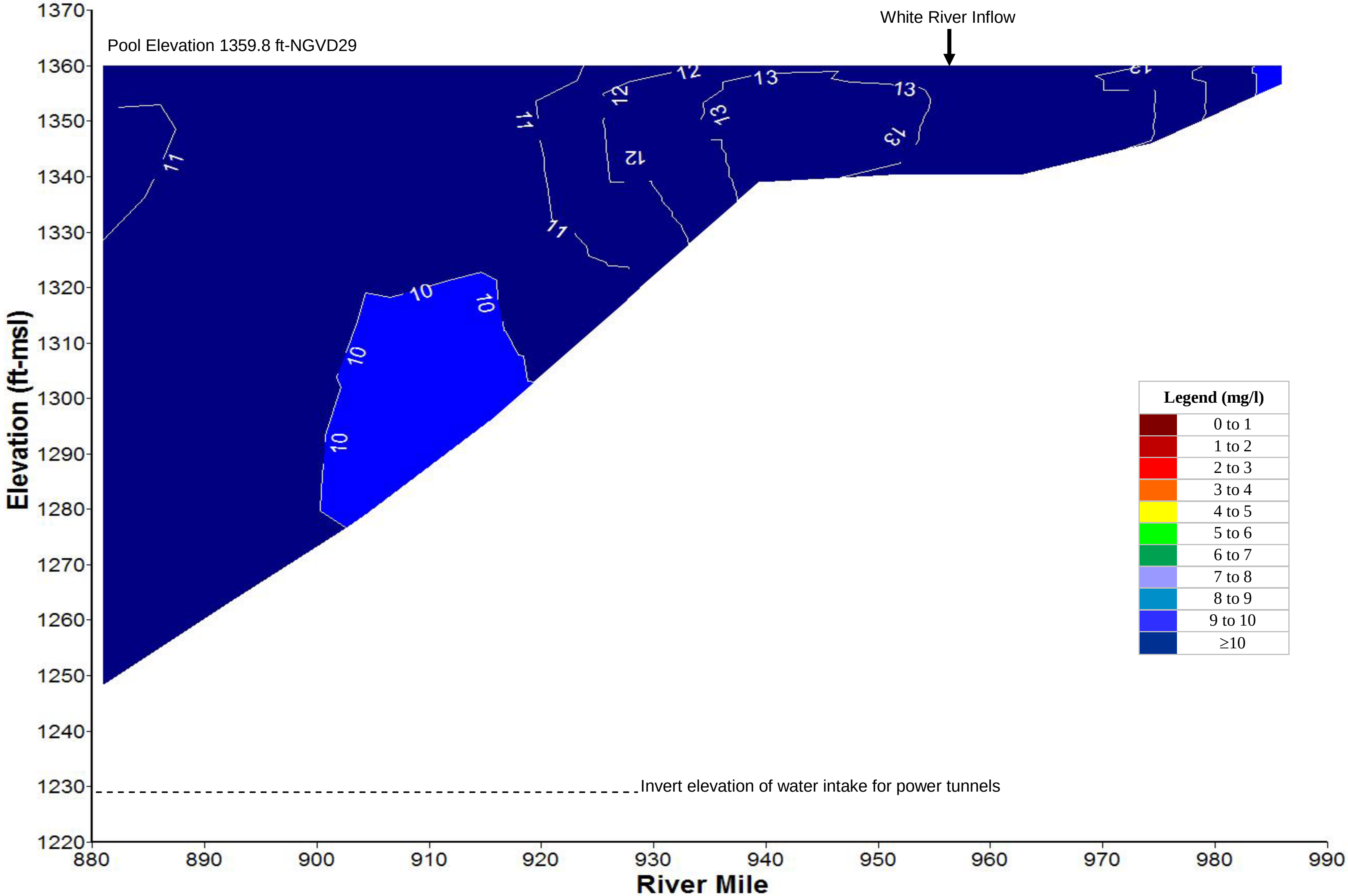

Plate 298. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Francis Case based on depth-profile dissolved oxygen concentrations measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on May 19, 2010.

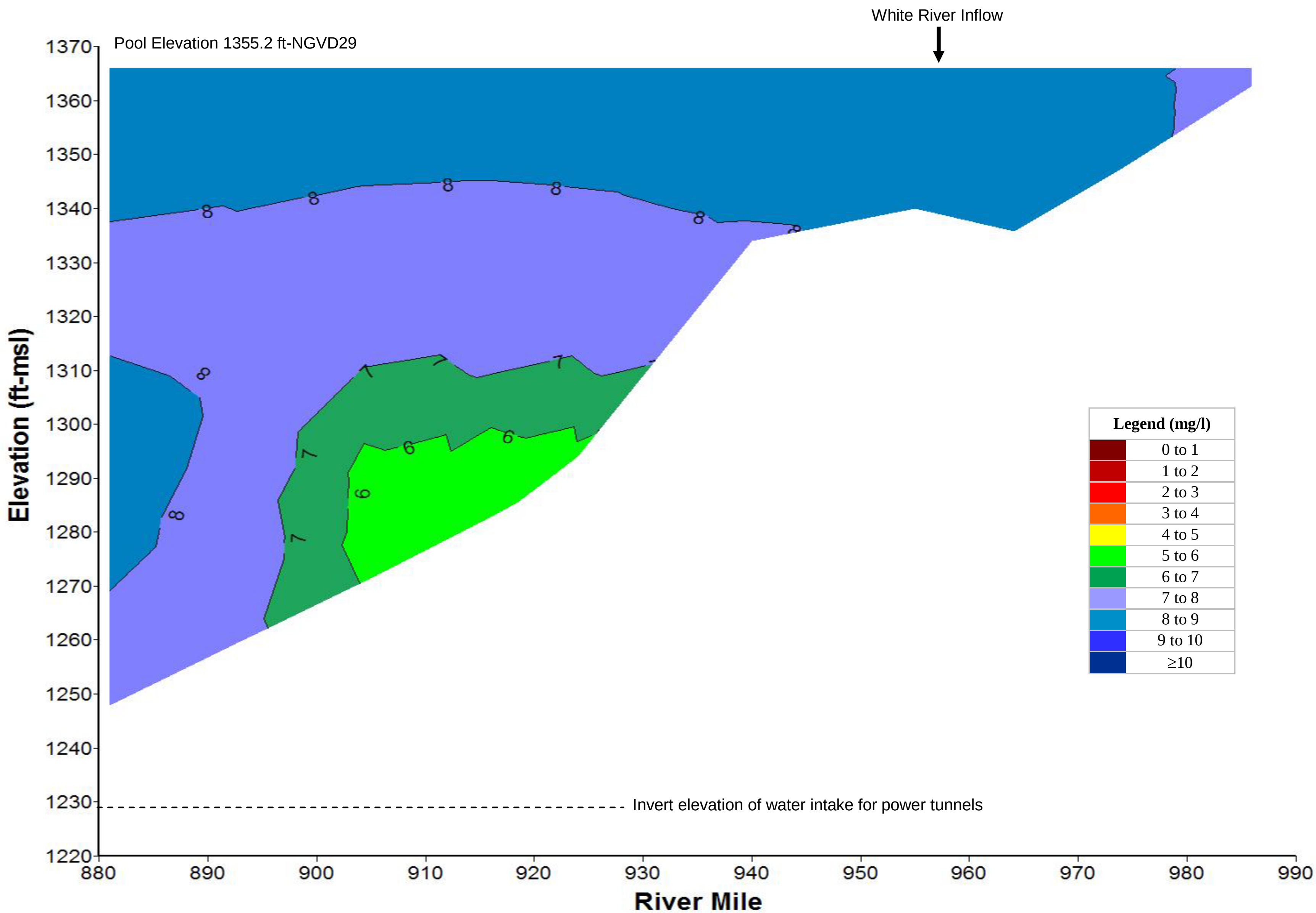

Plate 299. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Francis Case based on depth-profile dissolved oxygen concentrations measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0968DW, and BBDPP1 on June 17, 2010.

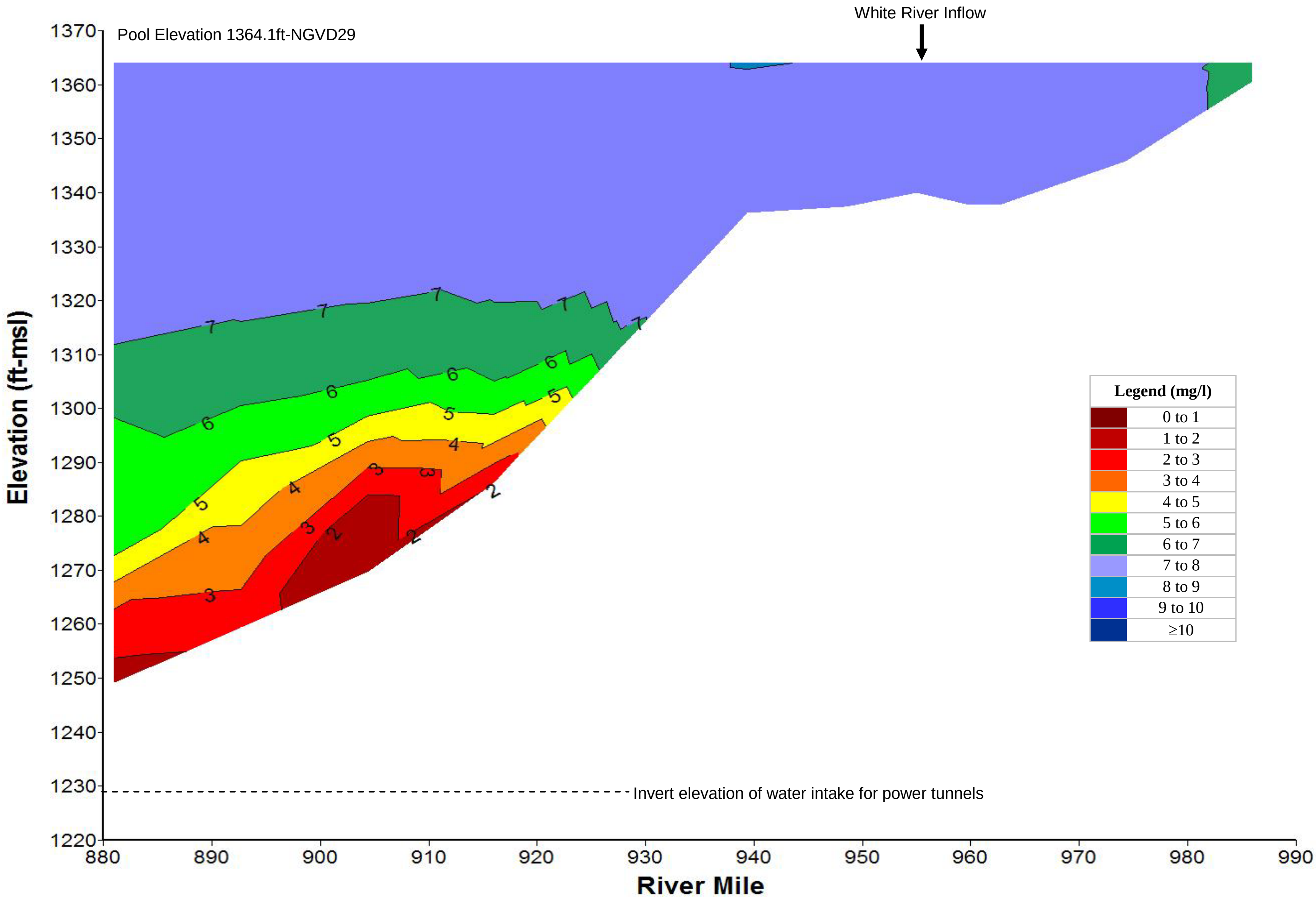

Plate 300. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Francis Case based on depth-profile dissolved oxygen concentrations measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on July 15, 2010.

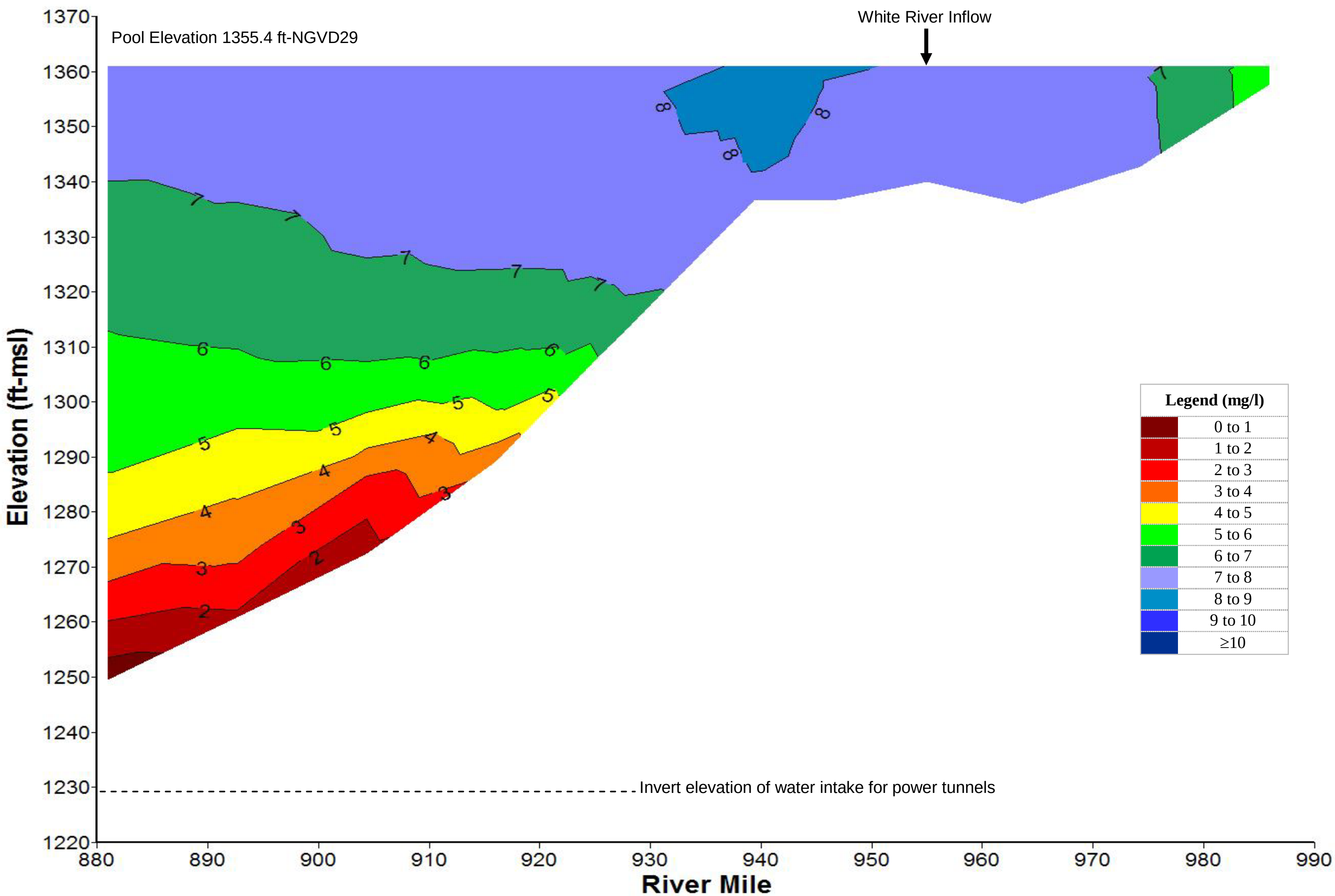

Plate 301. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Francis Case based on depth-profile dissolved oxygen concentrations measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on August 12, 2010.

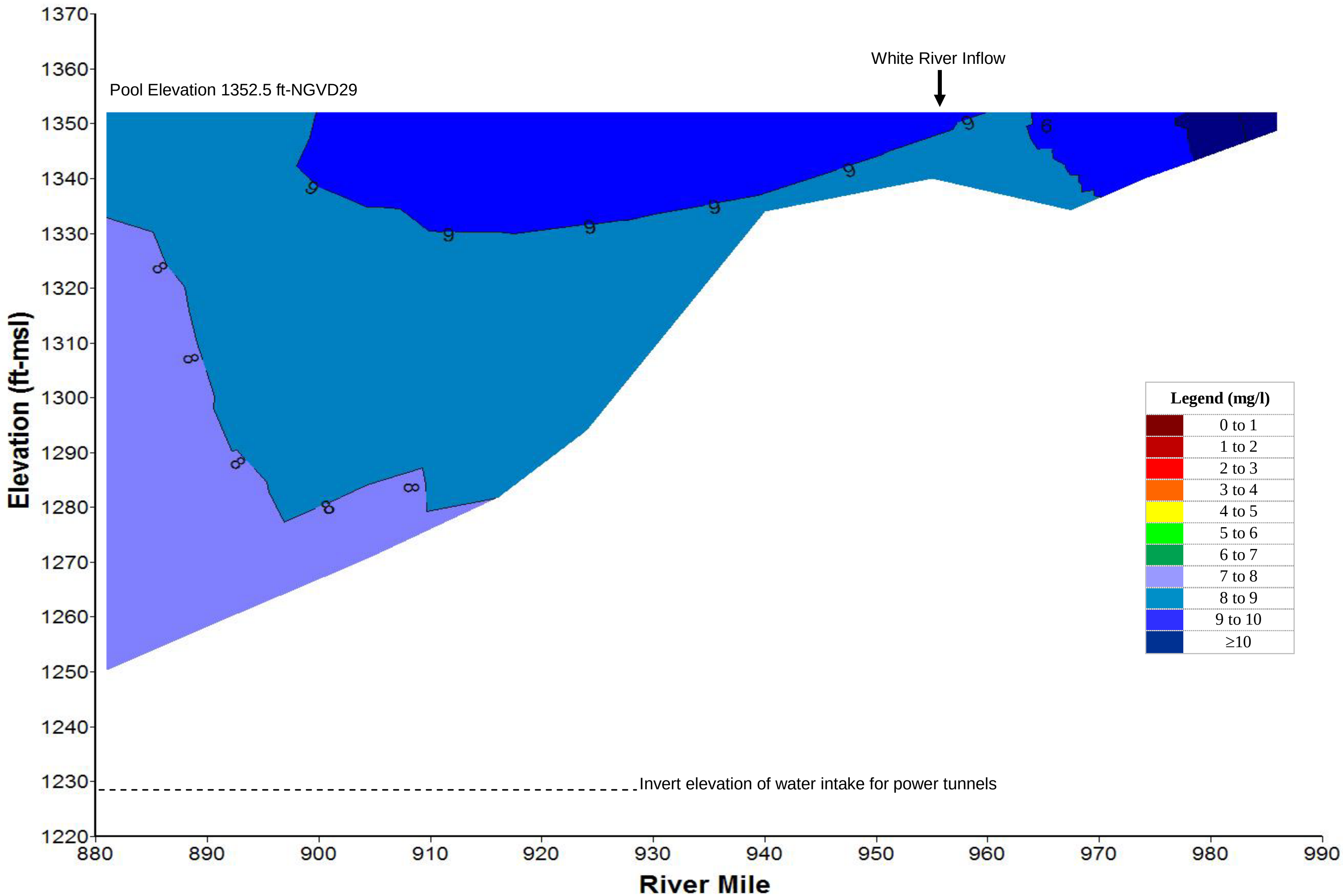

Plate 302. Longitudinal dissolved oxygen (mg/l) contour plot of Lake Francis Case based on depth-profile dissolved oxygen concentrations measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0968DW, and BBDPP1 on September 16, 2010.

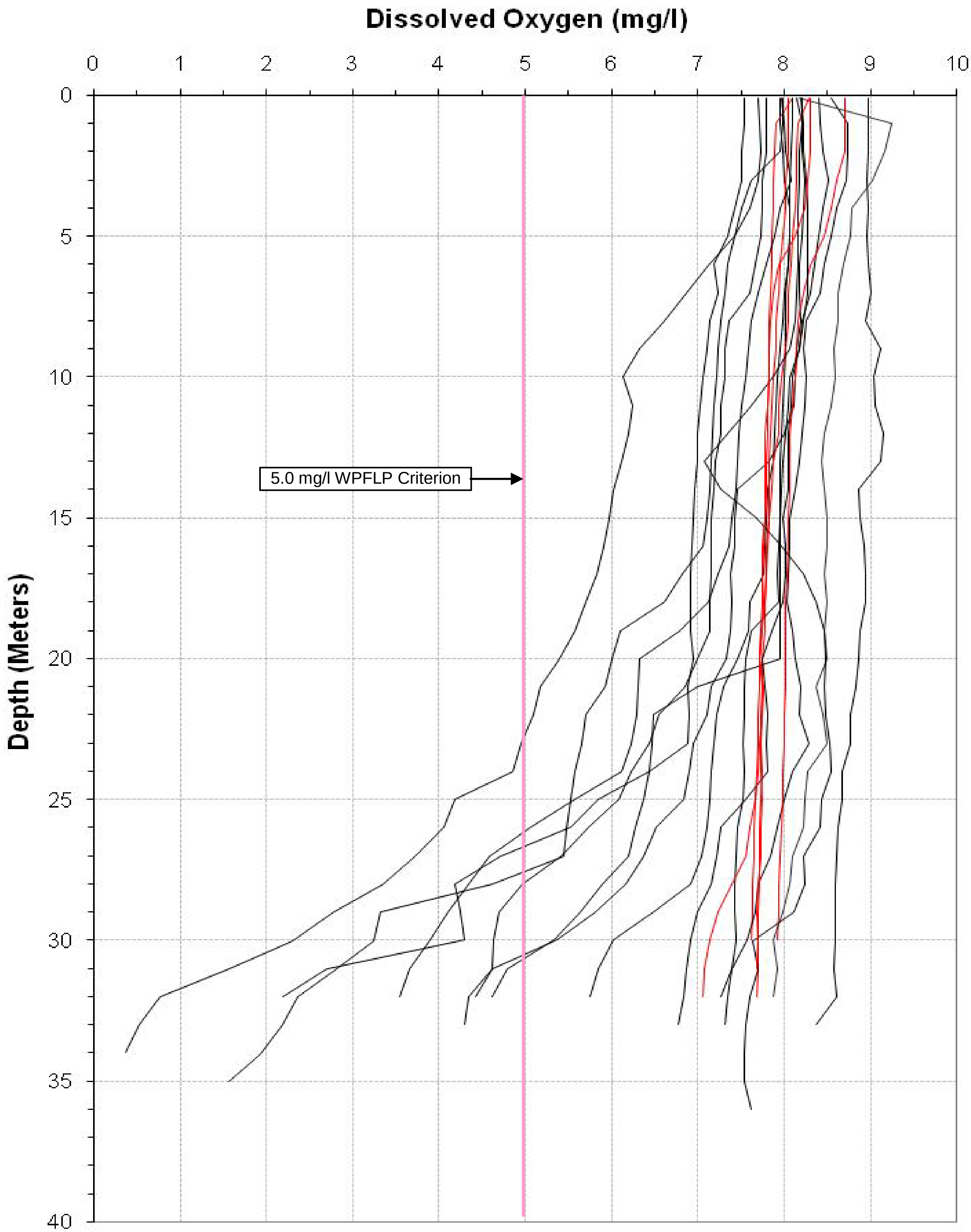

Plate 303. Dissolved oxygen depth profiles for Lake Francis Case generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., site FTRLK0880A) during the summer months over the 5-year period of 2006 to 2010.
(Note: Red profile plots were measured in the month of September.)

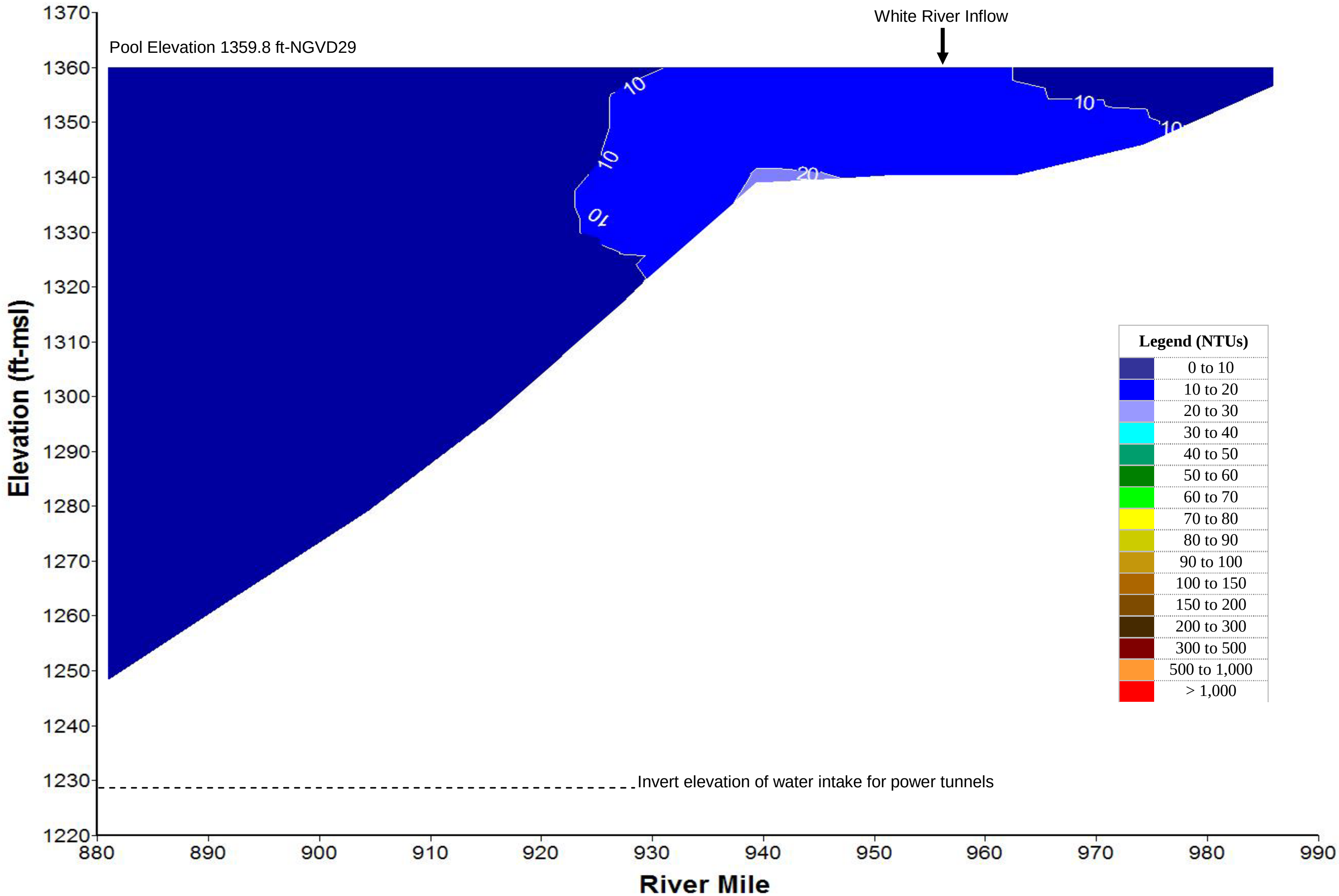

Plate 304. Longitudinal turbidity (NTU) contour plot of Lake Francis Case based on depth-profile turbidity levels measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on May 19, 2010.

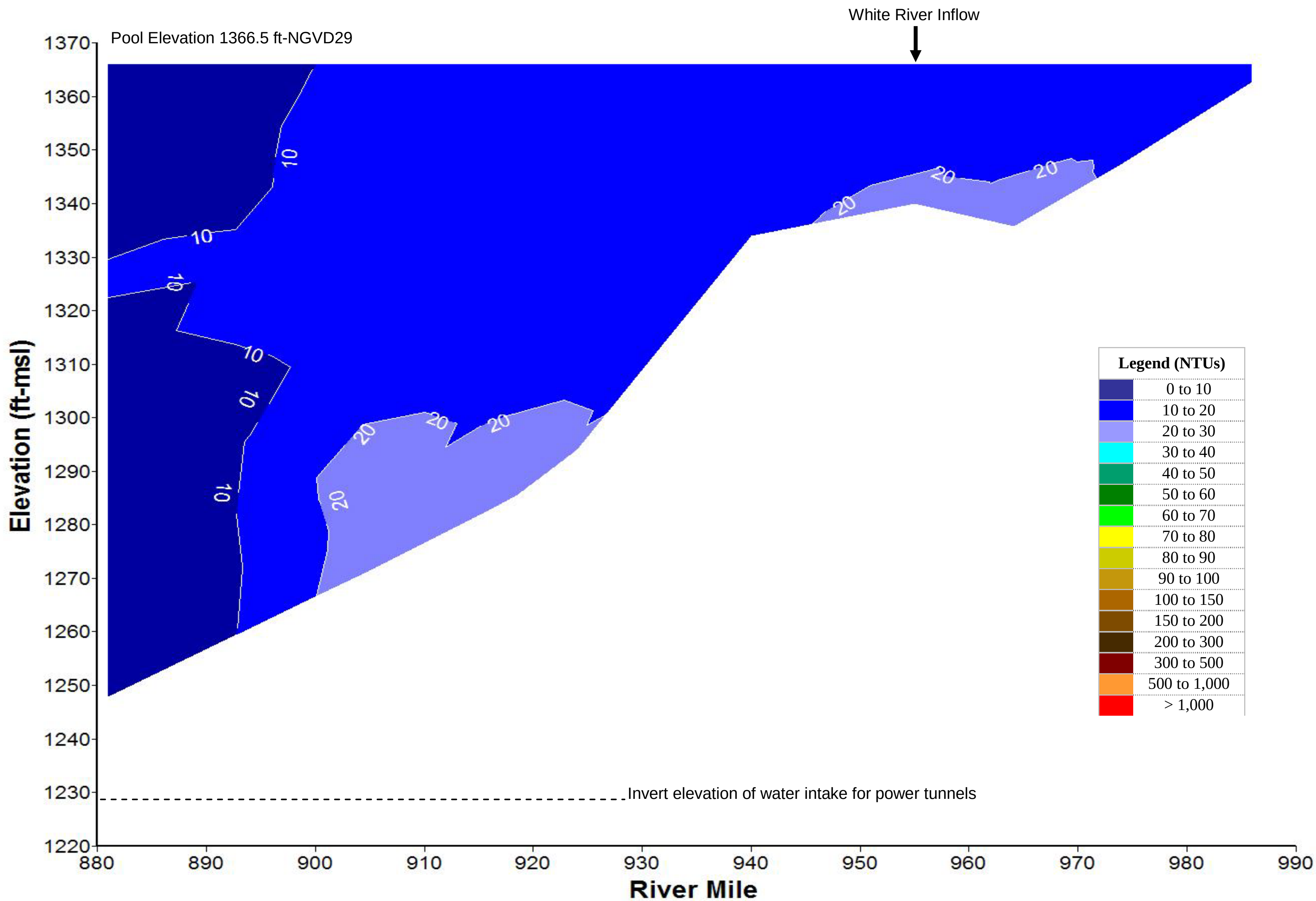

Plate 305. Longitudinal turbidity (NTU) contour plot of Lake Francis Case based on depth-profile turbidity levels measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0968DW, and BBDPP1 on June 17, 2010.

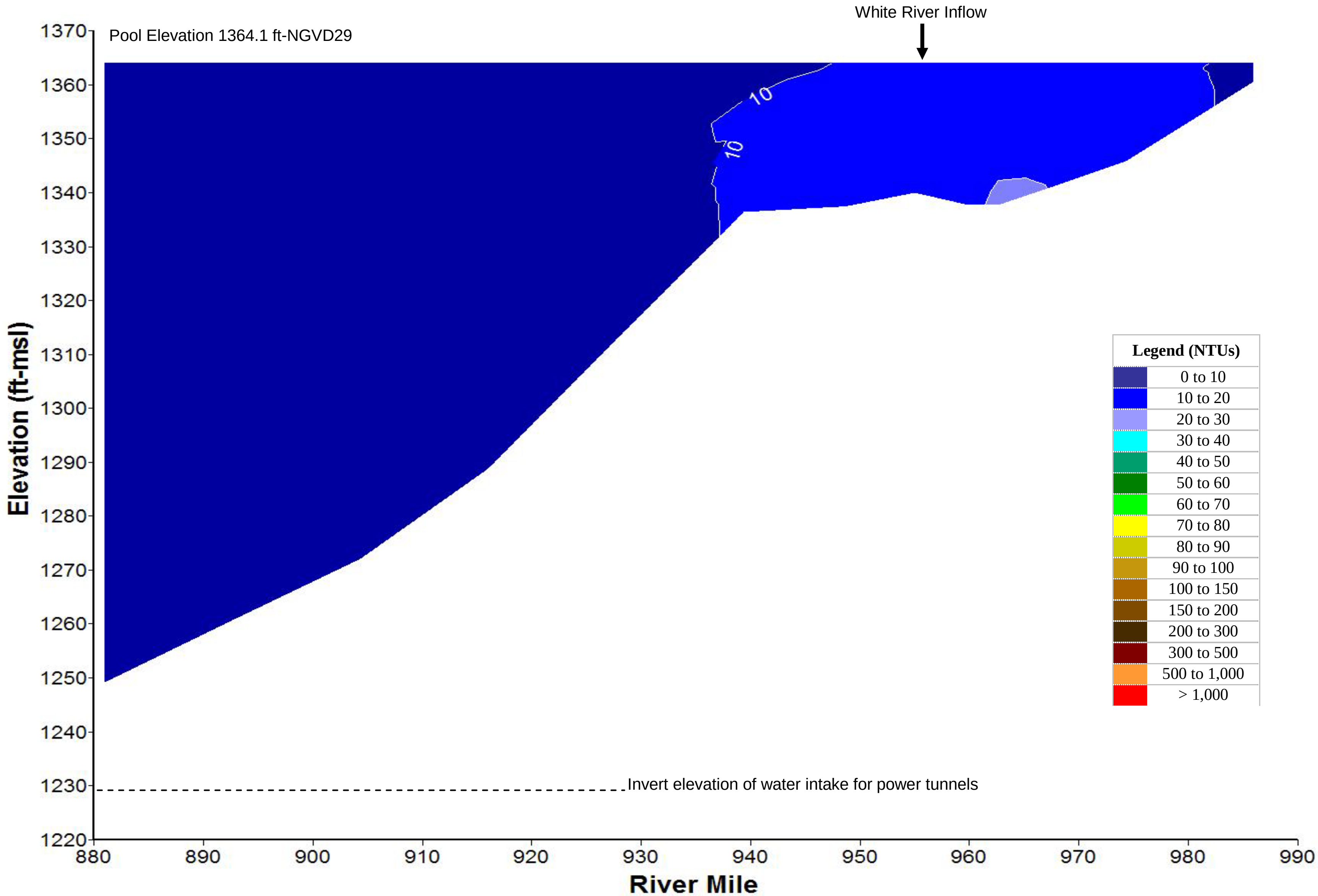

Plate 306. Longitudinal turbidity (NTU) contour plot of Lake Francis Case based on depth-profile turbidity levels measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on July 15, 2010.

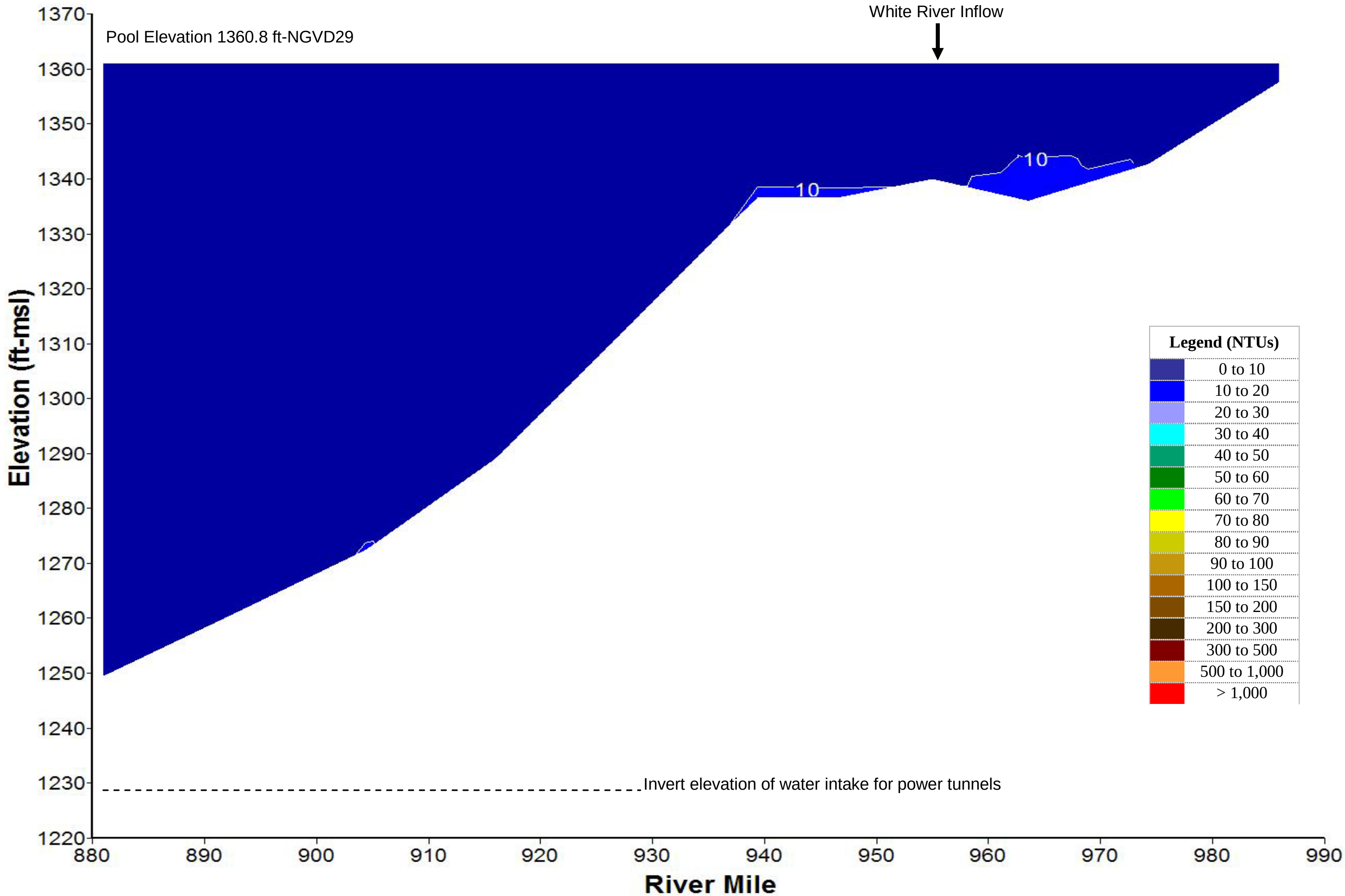

Plate 307. Longitudinal turbidity (NTU) contour plot of Lake Francis Case based on depth-profile turbidity levels measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0940DW, FTRLK0968DW, and BBDPP1 on August 12, 2010.

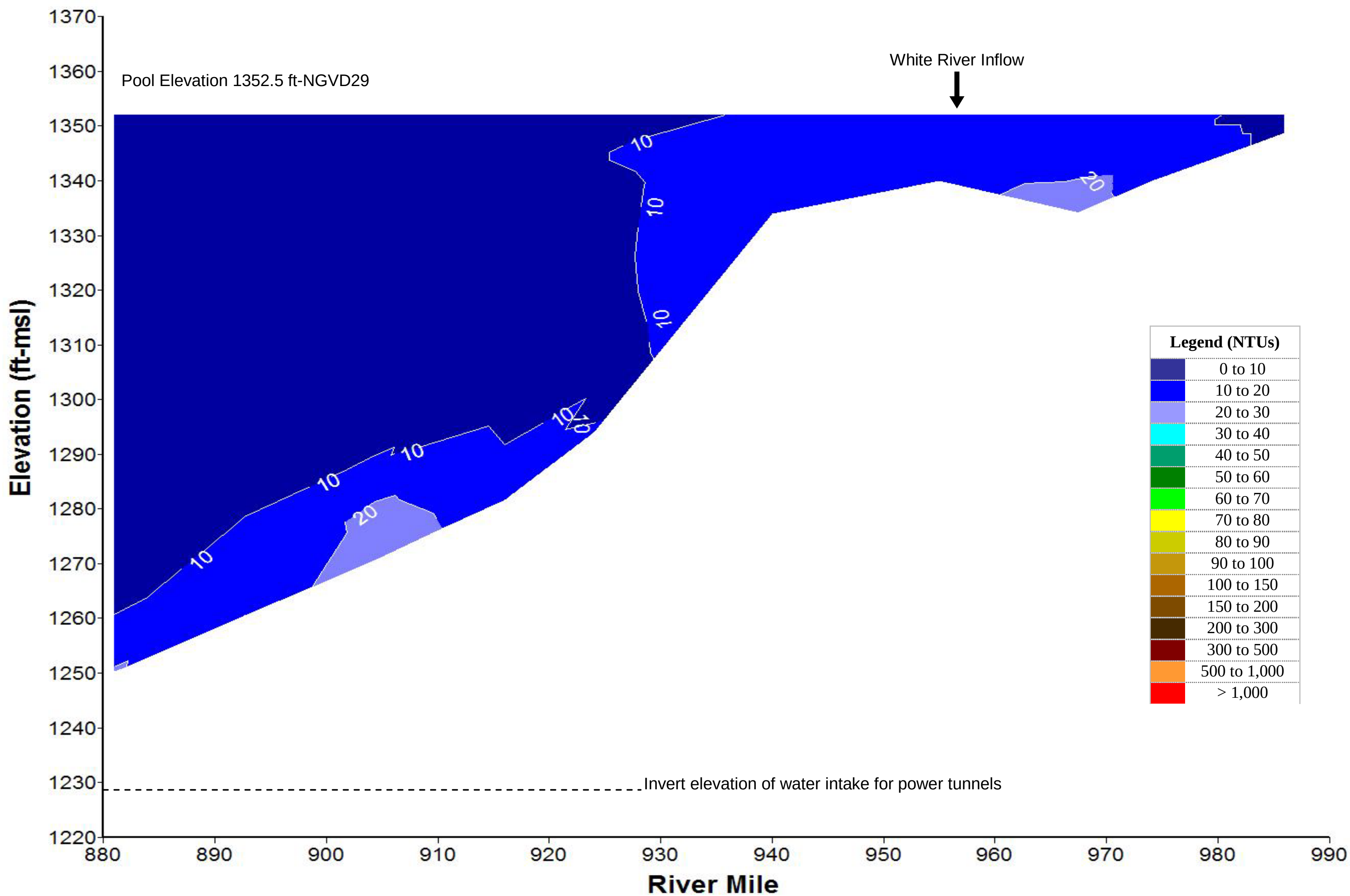

Plate 308. Longitudinal turbidity (NTU) contour plot of Lake Francis Case based on depth-profile turbidity levels measured at sites FTRLK0987A, FTRLK0911DW, FTRLK0968DW, and BBDPP1 on September 16, 2010.

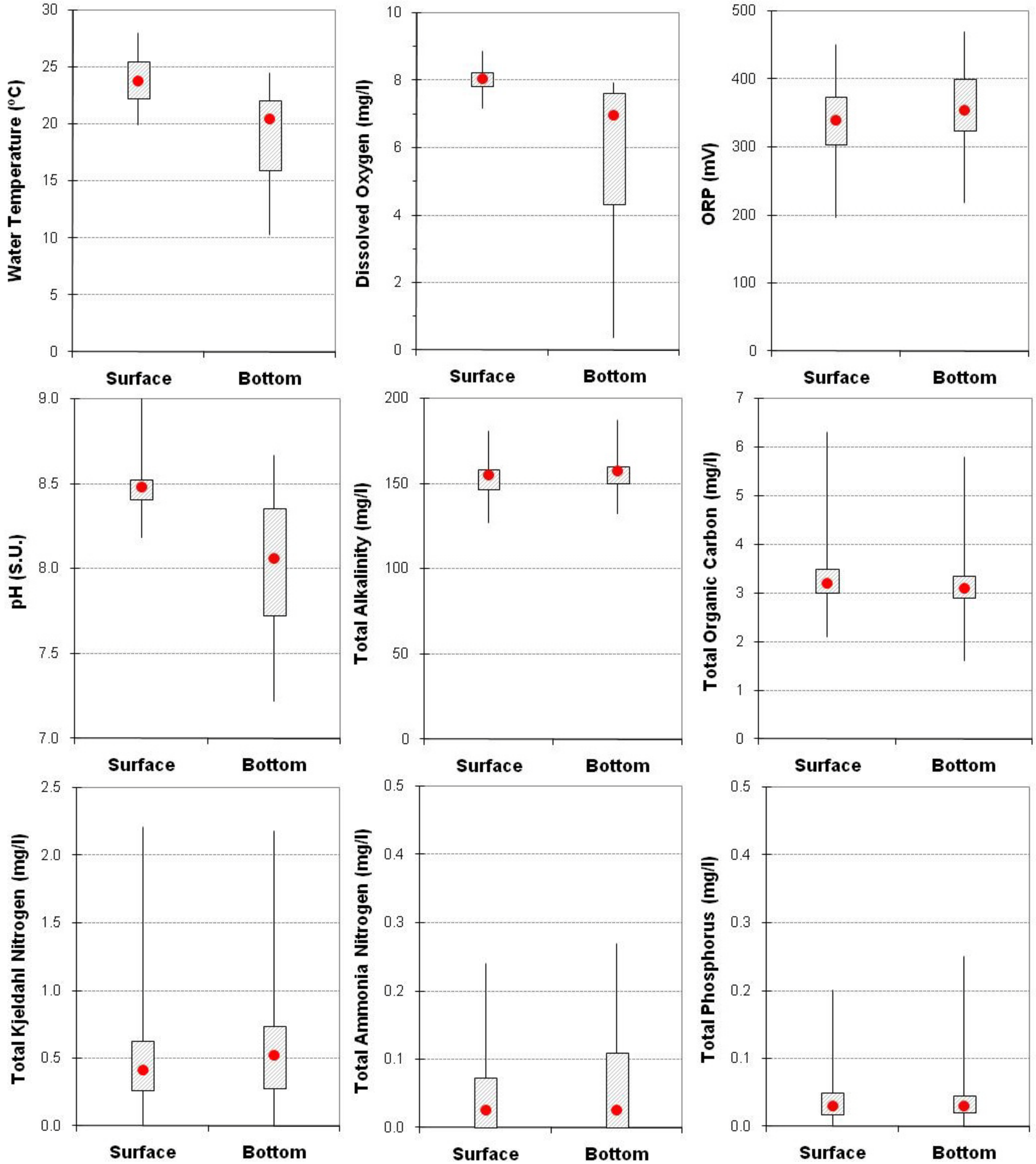

Plate 309. Box plots comparing paired surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus measurements taken in Lake Francis Case at site FTRLK0880A during the summer months of the 5-year period 2006 through 2010.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 310. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Francis Case at site FTRLK0880A during the 5-year period 2006 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
May 2006	1.5112	6	1.00	2	<0.01	0	-----	1	<0.01	0	-----	0	-----	0	-----
Jun 2006	0.2172	7	0.80	6	0.09	1	0.09	1	0.02	1	<0.01	0	-----	0	-----
Jul 2006	0.0395	7	0.88	5	0.08	0	-----	1	0.02	3	0.02	0	-----	1	<0.01
Aug 2006	0.2504	5	0.74	7	0.11	2	0.09	1	0.01	1	<0.01	1	0.03	1	0.03
Sep 2006	0.3912	6	0.81	11	0.11	0	-----	1	0.02	3	0.01	1	0.03	1	0.01
May 2007	1.1283	5	0.95	1	0.01	1	<0.01	1	0.02	0	-----	2	0.02	0	-----
Jun 2007	0.2493	3	0.38	4	0.41	1	<0.01	1	0.21	0	-----	0	-----	0	-----
Jul 2007	0.1017	8	0.61	8	0.15	0	-----	1	0.10	1	0.04	1	0.10	0	-----
Aug 2007	0.3128	8	0.39	8	0.03	2	0.01	2	0.03	3	<0.01	1	0.54	1	<0.01
Sep 2007	0.2283	7	0.70	11	0.13	0	-----	1	0.06	4	0.03	1	0.04	1	0.04
May 2008	0.7841	10	1.00	3	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	0	-----
Jun 2008	1.0969	6	0.97	4	<0.01	2	0.01	1	0.02	1	<0.01	0	-----	0	-----
Jul 2008	0.0001	3	0.06	0	-----	0	-----	1	0.94	1	<0.01	0	-----	0	-----
Aug 2008	0.0137	2	0.02	5	0.50	0	-----	1	0.35	1	<0.01	1	0.13	0	-----
Sep 2008	0.3765	6	0.80	13	0.05	0	-----	2	0.10	4	0.01	1	0.01	3	0.03
May 2009	1.5611	9	0.77	4	0.01	1	<0.01	2	0.21	1	<0.01	0	-----	1	0.01
Jun 2009	0.5341	7	0.03	7	0.44	0	-----	2	0.51	1	0.01	0	-----	0	-----
Jul 2009	0.4634	9	0.14	10	0.12	1	0.01	2	0.68	1	0.02	2	0.04	1	<0.01
Aug 2009	2.0956	9	0.07	12	0.13	2	0.18	1	0.04	2	0.01	2	0.54	2	0.02
Sep 2009	2.1778	10	0.89	5	0.06	0	-----	1	0.03	2	0.01	1	<0.01	1	<0.01
May 2010	1.1134	11	0.98	4	0.01	1	<0.01	0	-----	1	<0.01	2	0.01	0	-----
Jul 2010	0.1185	5	0.52	6	0.02	0	-----	1	0.39	5	0.05	2	0.02	1	<0.01
Sep 2010	0.4854	4	0.96	12	0.01	1	<0.01	2	0.02	4	<0.01	2	<0.01	2	0.01
Mean*	**0.6631**	**6.7**	**0.63**	**6.4**	**0.11**	**0.7**	**0.03**	**1.2**	**0.17**	**1.7**	**0.01**	**0.9**	**0.11**	**0.7**	**0.01**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 311. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Francis Case at site FTRLK0911DW during the 5-year period 2006 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
Jun 2006	0.0699	5	0.44	7	0.36	2	0.08	1	0.04	1	0.06	1	0.03	0	-----
Jul 2006	0.0986	2	0.34	5	0.13	0	-----	1	0.11	3	0.16	1	0.27	0	-----
Aug 2006	0.1333	5	0.11	12	0.44	1	0.01	1	0.14	4	0.14	1	0.15	1	0.02
Sep 2006	0.0836	10	0.32	15	0.43	0	-----	1	0.10	6	0.02	1	0.12	0	-----
Jun 2007	1.6974	6	0.89	8	0.06	2	0.01	1	0.03	0	-----	1	0.01	0	-----
Jul 2007	0.5291	6	0.04	7	0.02	1	0.01	1	0.02	3	0.88	1	0.04	0	----
Aug 2007	0.4238	6	0.93	9	0.02	3	<0.01	2	0.01	3	<0.01	1	0.05	0	-----
Sep 2007	1.0137	8	0.95	12	0.02	1	<0.01	2	<0.01	5	0.01	1	0.01	1	0.01
Jun 2008	0.6442	8	0.95	11	0.01	1	0.01	1	0.02	0	-----	0	-----	0	-----
Jul 2008	0.0003	4	0.87	6	0.02	1	<0.01	1	0.07	2	<0.01	1	0.04	0	-----
Aug 2008	0.1317	6	0.62	6	0.01	0	-----	1	0.05	3	0.32	1	0.01	0	-----
Sep 2008	0.4254	5	0.85	9	0.03	1	<0.01	2	0.07	6	0.02	2	0.02	1	<0.01
May 2009	0.6800	13	0.53	4	0.03	0	-----	2	0.44	1	<0.01	1	0.01	0	-----
Jun 2009	2.0004	4	0.38	1	<0.01	2	0.01	2	0.47	1	<0.01	1	0.14	0	-----
Jul 2009	0.1519	9	0.54	10	0.10	2	0.03	2	0.19	3	<0.01	1	0.13	0	-----
Aug 2009	0.7333	9	0.18	14	0.17	1	<0.01	2	0.51	4	0.05	1	0.08	2	0.01
Sep 2009	0.6554	7	0.02	13	0.04	1	<0.01	1	0.59	6	0.34	2	0.01	2	0.01
May 2010	2.4850	8	0.99	8	<0.01	1	<0.01	2	<0.01	0	-----	0	-----	0	-----
Jul 2010	0.9618	3	0.96	9	0.01	0	-----	1	<0.01	6	0.01	2	0.01	1	<0.01
Sep 2010	0.3049	10	0.63	17	0.06	1	0.01	2	0.28	6	0.01	3	0.01	1	<0.01
Mean*	**0.6612**	**6.7**	**0.58**	**9.2**	**0.10**	**1.1**	**0.01**	**1.5**	**0.16**	**3.2**	**0.12**	**1.2**	**0.06**	**0.5**	**0.01**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 312. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Francis Case at site FTRLK0940DW during the 5-year period 2006 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
Jun 2006	0.5189	11	0.92	9	0.05	0	-----	0	-----	1	0.03	0	-----	0	-----
Jul 2006	0.1196	11	0.81	8	0.07	1	<0.01	0	-----	1	0.06	1	0.05	1	0.01
Aug 2006	0.3200	12	0.72	15	0.12	1	0.01	1	<0.01	5	0.14	1	0.01	1	<0.01
Sep 2006	0.3654	18	0.83	10	0.11	1	0.03	0	-----	0	-----	1	0.04	0	-----
Jun 2007	7.7688	8	0.91	10	0.03	2	0.02	1	0.01	5	0.03	1	0.01	0	-----
Jul 2007	0.5830	12	0.50	8	0.01	0	-----	1	0.01	3	0.47	1	0.01	0	-----
Aug 2007	0.2103	10	0.48	11	0.22	1	<0.01	2	0.06	3	0.12	2	0.11	0	-----
Jun 2008	0.1457	10	0.84	9	0.05	2	0.04	1	0.06	1	<0.01	0	-----	0	-----
Jul 2008	0.0007	5	0.86	6	0.07	1	<0.01	1	0.01	6	0.06	2	<0.01	2	<0.01
Aug 2008	0.2179	11	0.95	4	<0.01	0	-----	1	<0.01	2	<0.01	1	0.01	3	0.01
May 2009	2.4139	13	0.89	5	0.02	2	<0.01	2	0.09	2	<0.01	1	<0.01	1	<0.01
Jun 2009	2.8839	11	0.95	7	0.01	1	0.02	1	0.02	1	<0.01	0	-----	0	-----
Jul 2009	0.9322	7	0.83	6	0.05	1	0.04	1	0.08	0	-----	1	<0.01	0	-----
Aug 2009	0.8763	10	0.21	15	0.06	2	0.15	2	0.39	6	0.04	2	0.15	2	<0.01
Sep 2009	0.5092	10	0.22	11	0.09	2	0.05	1	0.46	5	0.15	2	0.03	2	0.01
May 2010	5.4668	8	0.98	5	0.02	2	<0.01	0	-----	0	-----	0	-----	0	-----
Jul 2010	2.6577	8	0.99	14	0.01	0	-----	1	<0.01	2	<0.01	1	0.01	0	-----
Mean*	**1.5288**	**10.3**	**0.76**	**9.0**	**0.06**	**1.1**	**0.03**	**0.9**	**0.10**	**2.5**	**0.08**	**1.0**	**0.03**	**0.7**	**<0.01**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 313. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Lake Francis Case at site FTRLK0968DW during the 5-year period 2006 through 2010.

Date	Total Sample Biovolume (mm^3/L)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
Jun 2006	3.0422	9	0.94	9	0.04	1	<0.01	1	<0.01	2	0.01	1	<0.01	0	-----
Jul 2006	0.2351	7	0.24	6	0.72	1	<0.01	1	0.01	1	0.03	0	-----	1	<0.01
Aug 2006	0.8426	19	0.91	14	0.04	2	<0.01	1	<0.01	6	0.03	1	0.01	1	<0.01
Sep 2006	0.2708	17	0.80	11	0.14	1	0.01	1	<0.01	1	<0.01	1	0.04	2	0.01
Jun 2007	1.0735	5	0.71	11	0.14	2	0.01	1	0.03	1	<0.01	1	0.11	0	-----
Jul 2007	0.4050	14	0.42	6	0.02	1	<0.01	1	0.05	1	0.37	1	0.12	0	0.01
Aug 2007	0.1621	11	0.55	6	0.03	2	0.02	1	0.01	3	<0.01	1	0.31	2	0.08
Sep 2007	0.1219	8	0.73	6	0.03	1	<0.01	1	0.05	5	0.18	0	-----	0	-----
Jun 2008	1.1620	8	0.96	9	0.01	2	<0.01	1	0.03	1	<0.01	0	-----	0	-----
Jul 2008	0.0002	4	0.86	2	0.01	0	-----	1	0.01	6	0.12	0	-----	0	-----
Aug 2008	0.1335	10	0.94	3	0.01	0	-----	1	0.03	3	<0.01	1	0.01	0	-----
Sep 2008	0.1040	10	0.86	2	0.02	1	<0.01	2	0.08	1	<0.01	0	-----	3	0.04
May 2009	2.1654	11	0.85	3	<0.01	0	-----	2	0.14	0	-----	1	0.01	0	-----
Jun 2009	1.6830	9	0.36	5	0.13	0	-----	2	0.51	0	-----	0	-----	0	-----
Jul 2009	0.8086	15	0.60	7	0.13	1	<0.01	2	0.26	0	-----	1	0.01	2	<0.01
Aug 2009	0.4145	12	0.29	8	0.04	2	0.01	1	0.05	3	0.02	1	0.59	0	-----
Sep 2009	0.4559	10	0.44	12	0.14	1	0.10	2	0.26	3	0.04	1	0.01	2	0.01
May 2010	2.9302	10	0.97	8	0.02	1	<0.01	1	0.01	0	-----	0	-----	1	<0.01
Jul 2010	1.0440	8	0.97	9	0.01	0	-----	2	0.01	2	<0.01	2	<0.01	3	<0.01
Sep 2010	0.7013	14	0.96	5	0.01	0	-----	2	0.01	3	0.02	1	<0.01	1	<0.01
Mean*	**0.8878**	**10.6**	**0.72**	**7.1**	**0.08**	**1.0**	**0.01**	**1.4**	**0.08**	**2.1**	**0.05**	**0.7**	**0.09**	**0.9**	**0.01**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 314. Estimated biomass, number of species, and percent composition (based on biomass) by taxonomic grouping for zooplankton tow samples collected in Lake Francis Case at Sites FTRLK0880A, FTRLK0911DW, FTRLK0940DW, and FTRLK0968DW during 2010.

Date	Estimated Biomass (µg/L dry wt.)	Cladocerans		Copepods		Rotifers	
		No. of Species	Percent Comp.	No. of Species	Percent Comp.	No. of Species	Percent Comp.
Site FTRLK0880A – Near Dam							
May 2010	17.266	1	0.27	3	0.65	9	0.08
July 2010	16.599	1	0.63	5	0.37	3	<0.01
Sept 2010	23.517	4	0.76	5	0.24	7	<0.01
Mean	**19.127**	**2.0**	**0.55**	**4.3**	**0.42**	**6.3**	**0.03**
Site FTRLK0911DW – Platte Creek							
May 2010	33.094	1	0.16	2	0.28	7	0.56
July 2010	67.000	3	0.82	4	0.18	10	<0.01
Sept 2010	42.548	3	0.40	6	0.58	8	0.02
Mean	**47.547**	**2.3**	**0.46**	**4.0**	**0.35**	**8.3**	**0.29**
Site FTRLK0940DW – Elm Creek							
May 2010	51.646	1	0.04	2	0.71	9	0.25
July 2010	255.594	2	0.82	5	0.18	9	<0.01
Sept 2010	No Data						
Mean	**153.62**	**1.5**	**0.43**	**3.5**	**0.45**	**9.0**	**0.25**
Site FTRLK0968DW – Chamberlain							
May 2010	60.591	1	0.07	3	0.56	7	0.37
July 2010	38.094	2	0.64	4	0.30	7	0.06
Sept 2010	17.035	3	0.41	6	0.45	9	0.14
Mean	**38.573**	**2.0**	**0.37**	**4.3**	**0.44**	**7.7**	**0.19**

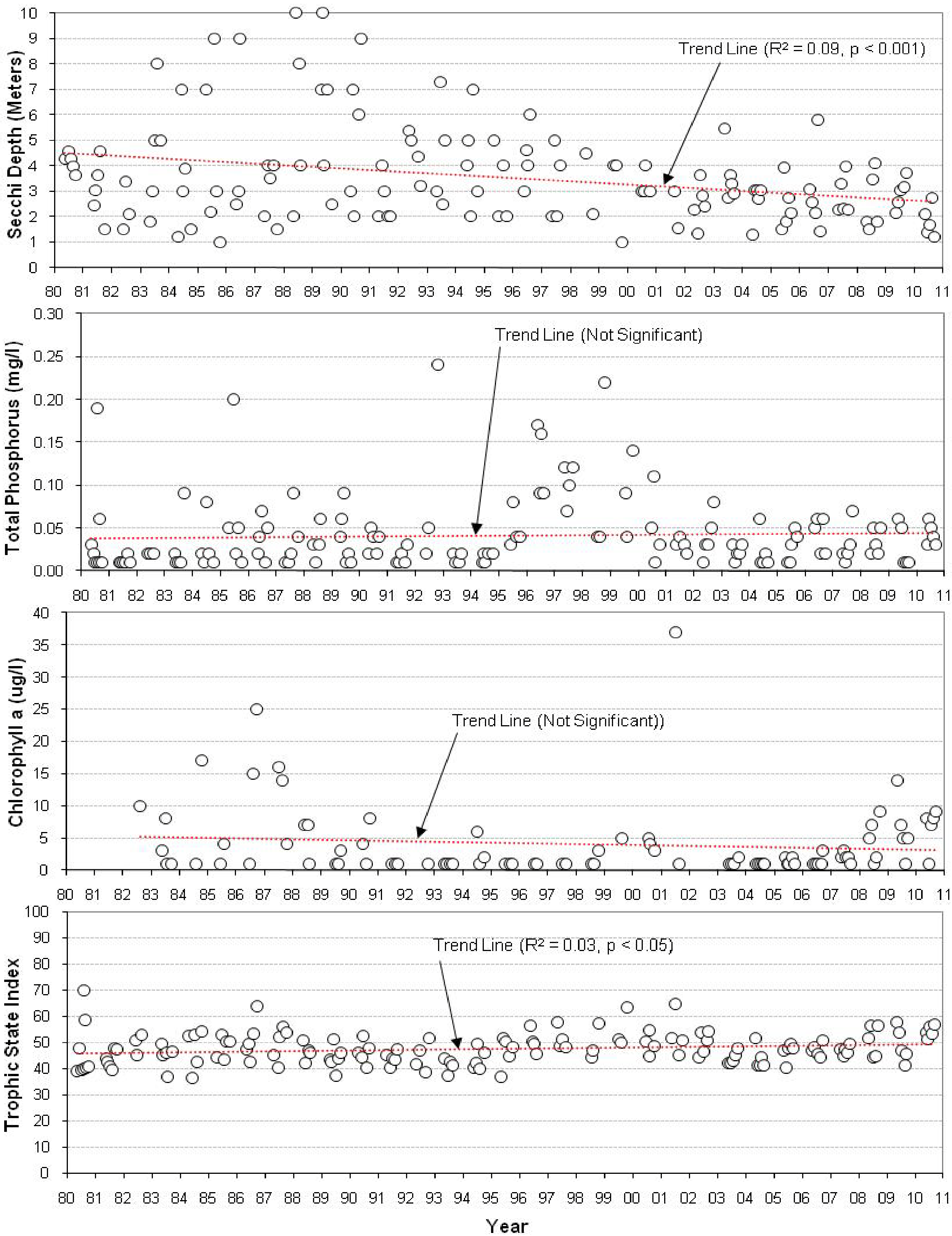

Plate 315. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Lake Francis Case at the near-dam, ambient site (i.e., site FTRLK0880A) over the 31-year period of 1980 through 2010.

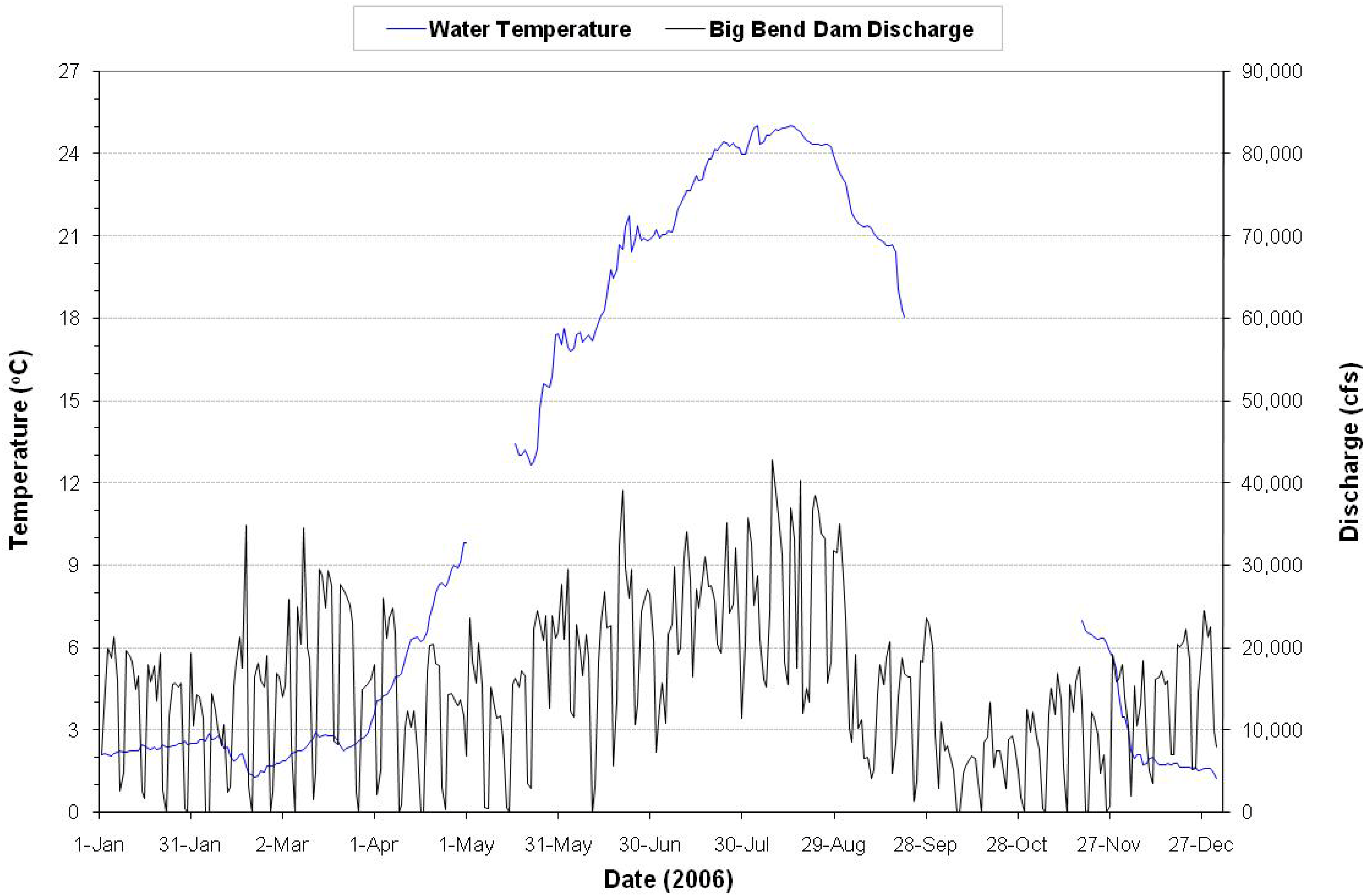

Plate 316. Mean daily water temperature and discharge of the Missouri River at Big Bend Dam (i.e., site BBDPP1) for 2006. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Big Bend Dam.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

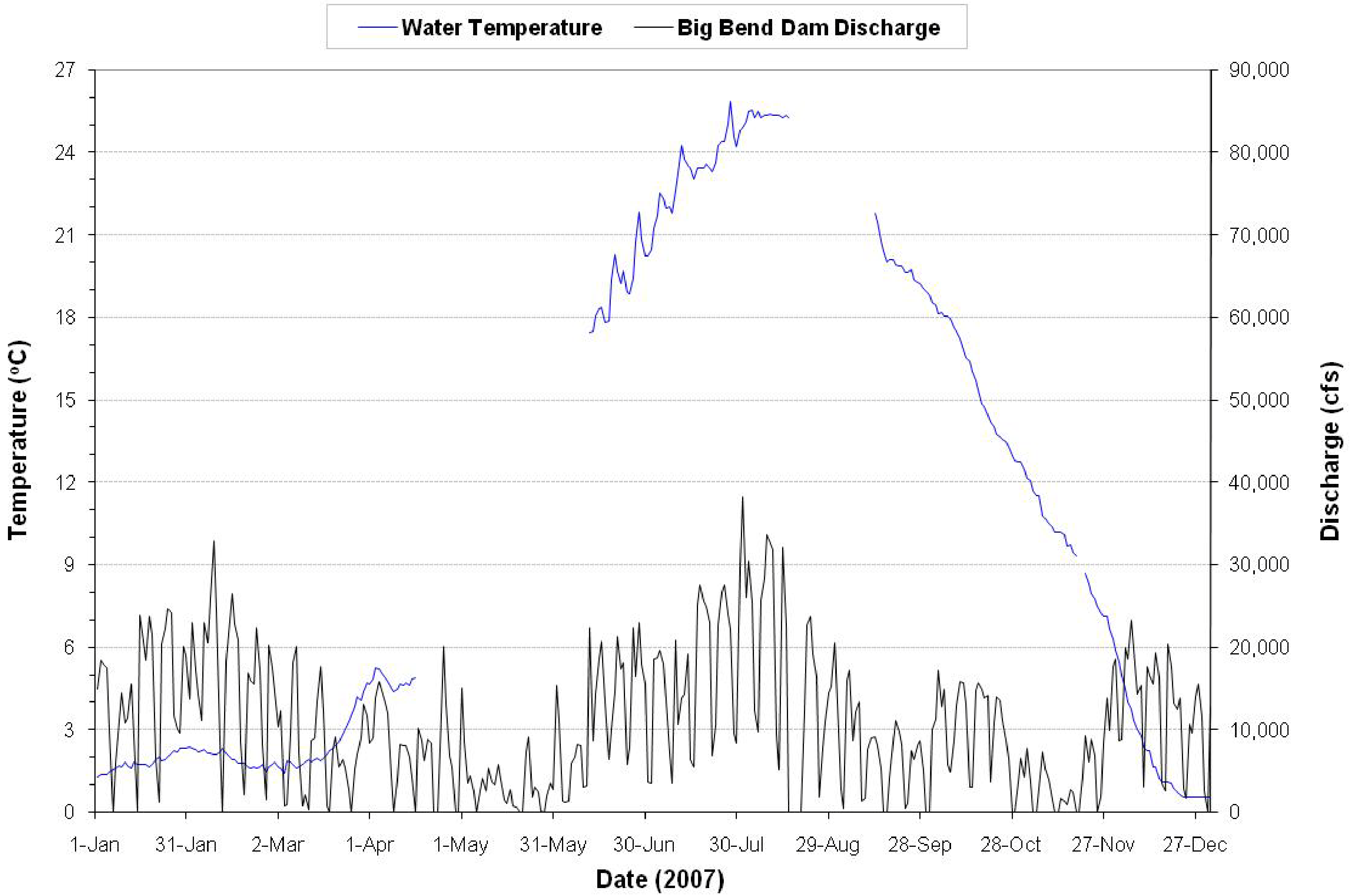

Plate 317. Mean daily water temperature and discharge of the Missouri River at Big Bend Dam (i.e., site BBDPP1) for 2007. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Big Bend Dam.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

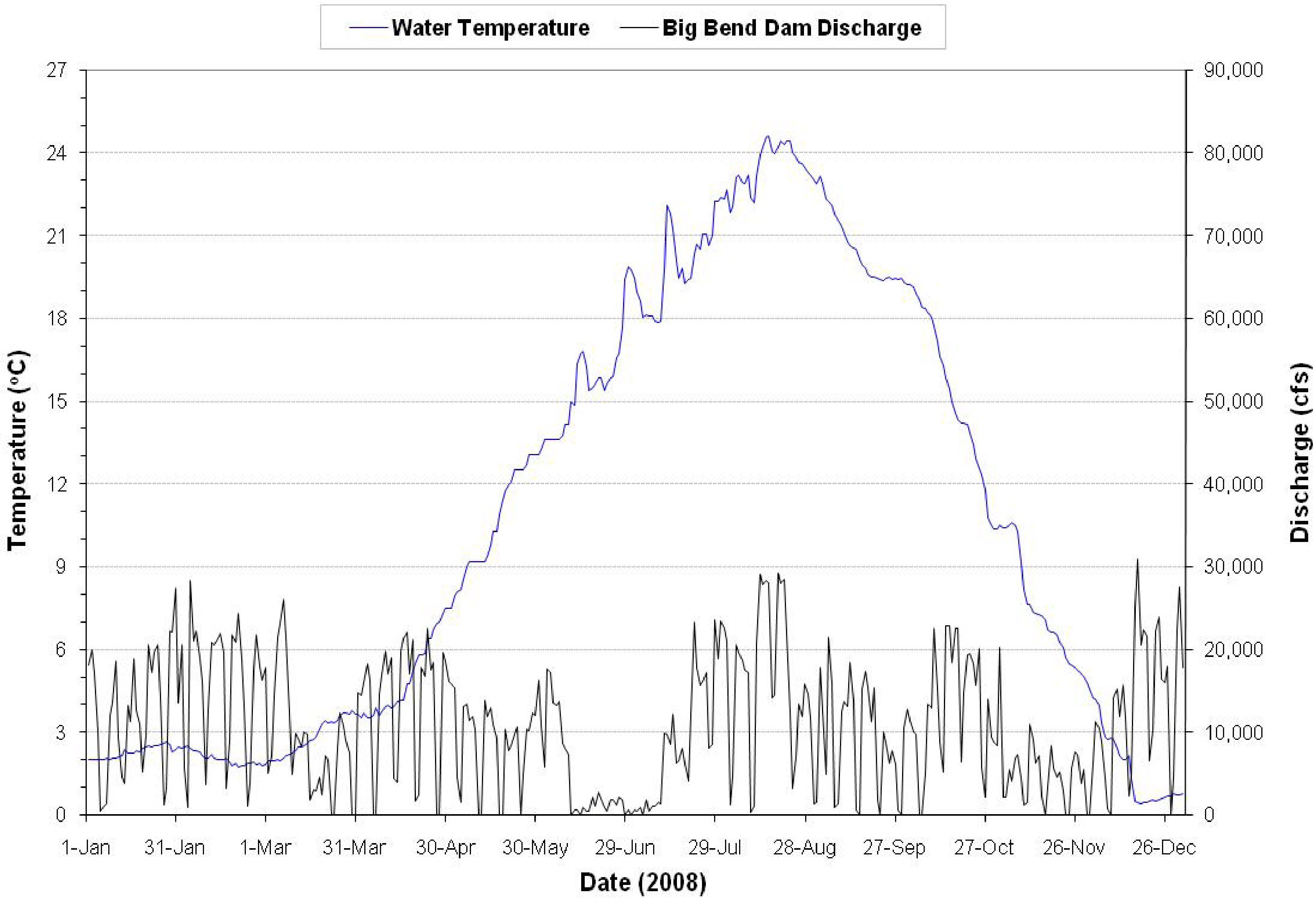

Plate 318. Mean daily water temperature and discharge of the Missouri River at Big Bend Dam (i.e., site BBDPP1) for 2008. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Big Bend Dam.

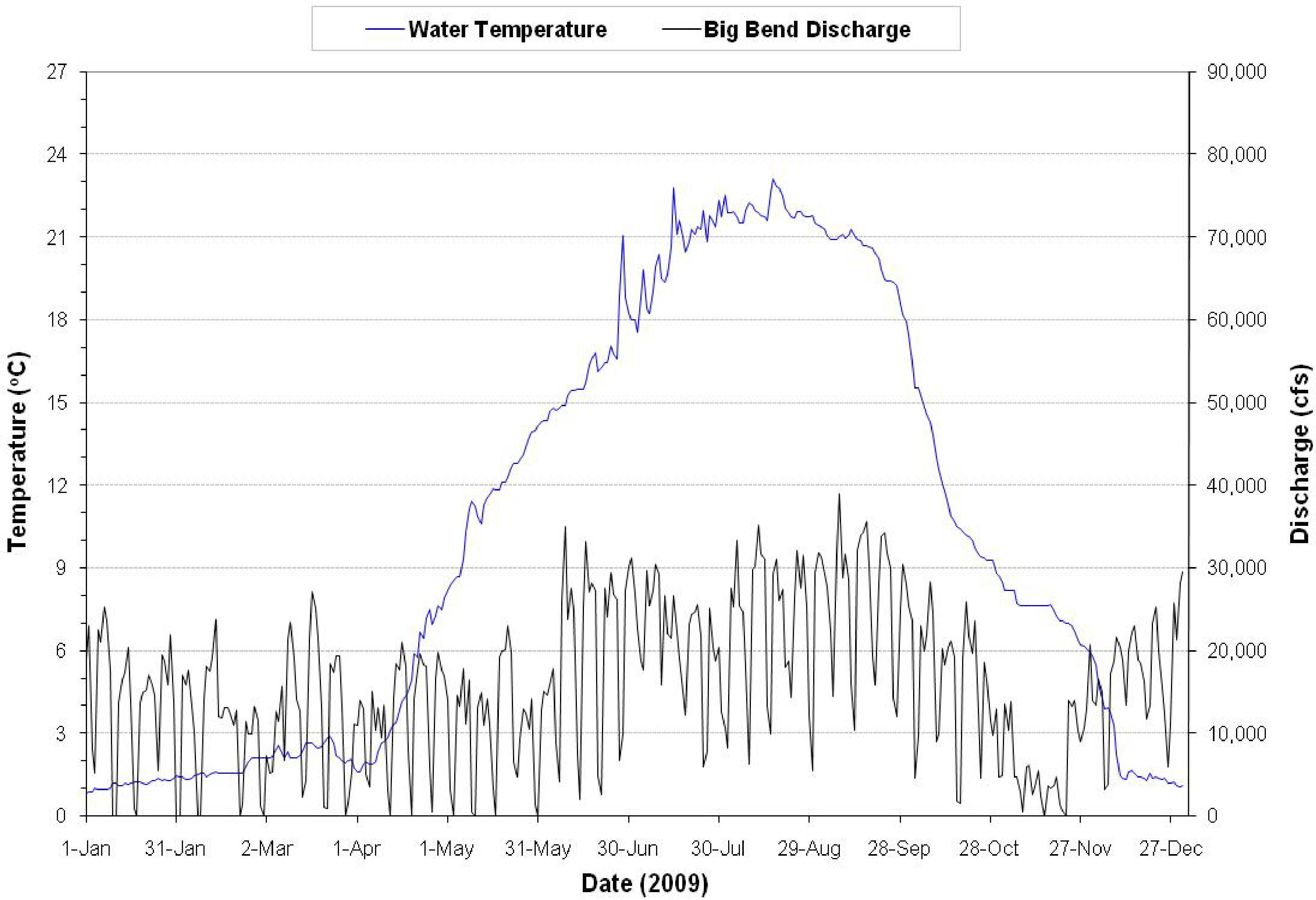

Plate 319. Mean daily water temperature and discharge of the Missouri River at Big Bend Dam (i.e., site BBDPP1) for 2009. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Big Bend Dam.

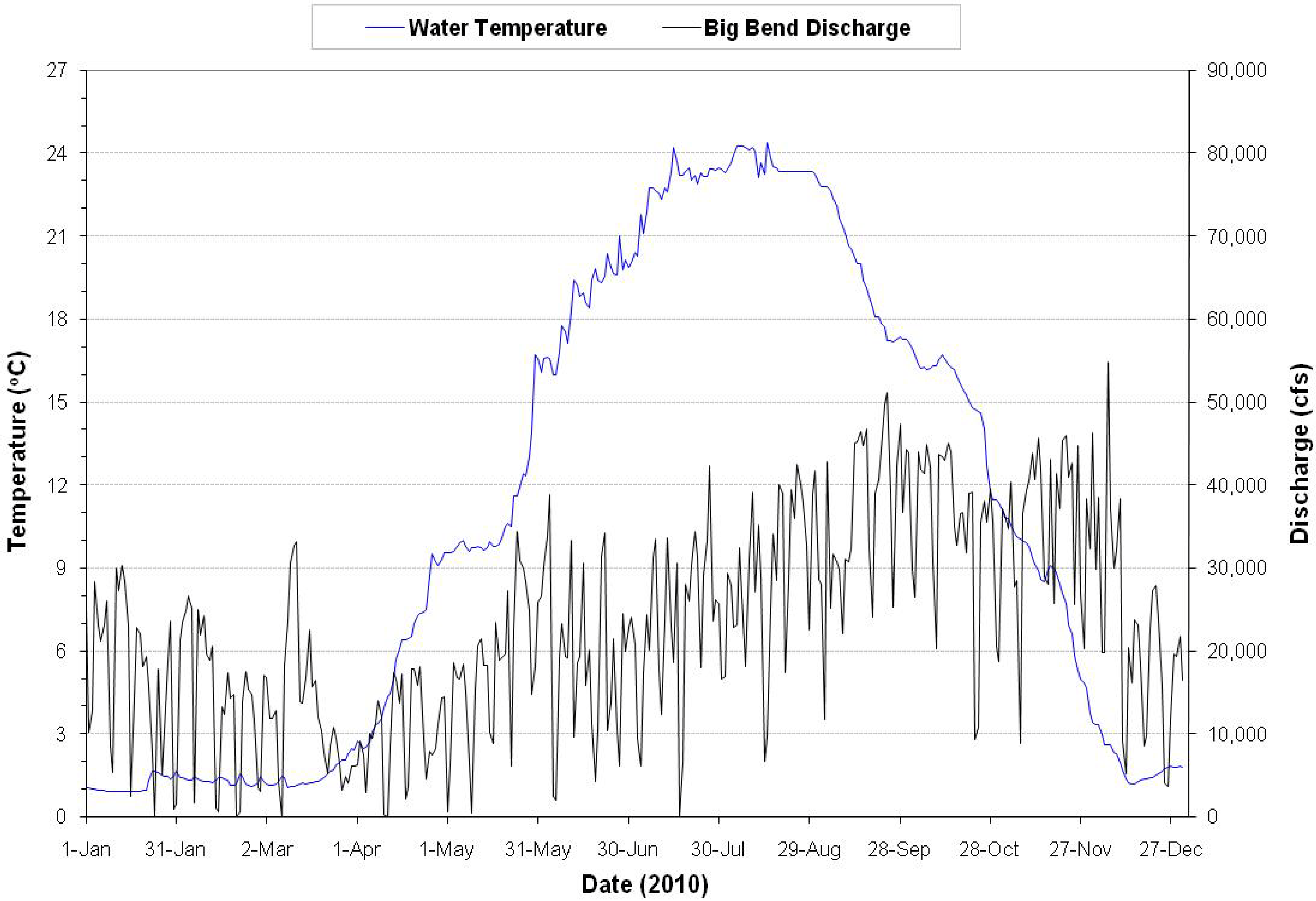

Plate 320. Mean daily water temperature and discharge of the Missouri River at Big Bend Dam (i.e., site BBDPP1) for 2010. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Big Bend Dam.

Plate 321. Summary of water quality conditions monitored on water discharged through Fort Randall Dam (i.e., site FTRPP1) during the 5-year period of 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Dam Discharge – Hydro (cfs)	1	50	20,958	19,222	145	41,200	-----	-----	-----
Dam Discharge – Spillway (cfs)	1	2	9,257	9,257	6,181	12,332	-----	-----	-----
Water Temperature (°C)	0.1	48	11.8	10.4	0.6	25.7	27(1,4)	0	0%
Dissolved Oxygen (mg/l)	0.1	48	10.0	10.5	5.2	13.8	5(1,5)	0	0%
Dissolved Oxygen (% Sat.)	0.1	48	92.8	95.4	52.3	104.2	-----	-----	-----
pH (S.U.)	0.1	42	8.2	8.3	6.8	8.7	6.5(1,2,5), 9.0(1,2,4), 9.5(3,4)	0	0%
Specific Conductance (umhos/cm)	1	48	721	729	580	772	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	41	359	358	214	471	-----	-----	-----
Turbidity (NTU)	1	40	-----	3	n.d.	22	-----	-----	-----
Alkalinity, Total (mg/l)	7	50	159	158	129	191	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	48	3.4	3.2	2.1	5.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	50	10	11	n.d.	22	-----	-----	-----
Chloride, Dissolved (mg/l)	1	39	12	12	9	14	438(2,4), 250(2,6)	0	0%
Color (APHA)	1	9	8	7	5	13	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	50	479	478	314	612	1,750(2,4), 1,000(2,7), 3,500(3,4), 2,000(3,6)	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	50	-----	n.d.	n.d.	0.29	4.7 (1,4,7), 1.4 (1,6,7)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	50	0.5	0.4	n.d.	3.6	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	50	-----	n.d.	n.d.	0.42	10(2,4)	0	0%
Nitrogen, Total (mg/l)	0.1	50	0.6	0.5	n.d.	3.6	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	47	-----	n.d.	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	50	-----	0.02	n.d.	0.25	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	50	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	50	205	209	117	236	875(2,4), 500(2,6)	0	0%
Suspended Solids, Total (mg/l)	4	50	-----	n.d.	n.d.	14	158(1,4), 90(1,6)	0	0%

n.d. = Not detected, b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of warmwater permanent fish life propagation waters.
(2) Criteria for the protection of domestic water supply waters.
(3) Criteria for the protection of commerce and industry waters.
(4) Daily maximum criterion (monitoring results directly comparable to criterion).
(5) Daily minimum criterion (monitoring results directly comparable to criterion).
(6) 30-day average criterion (monitoring results not directly comparable to criterion).
(7) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

Plate 322. Summary of annual metals and pesticide levels monitored on water discharged through Fort Randall Dam (i.e., site FTRPP1) during the 5-year period of 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.[A]	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Aluminum, Total (ug/l)	25	5	100	99	71	130	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	0.6	-----	-----	-----
Antimony, Total (ug/l)	0.5	4	-----	n.d.	n.d.	0.7	5.6(3)	0	0%
Arsenic, Dissolved (ug/l)	1	4	2	2	1	2	340(1), 150(2)	0, 0	0%, 0%
Arsenic, Total (ug/l)	1	4	2	2	1	2	0.018(3)	4	100%
Barium, Dissolved (ug/l)	5	4	32	32	30	36	-----	-----	-----
Barium, Total (ug/l)	5	4	34	33	30	40	-----	-----	-----
Beryllium, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Beryllium, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	4(3)	0	0%
Cadmium, Dissolved (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	4.3(1), 0.42(2)	0	0%
Cadmium, Total (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	5(3)	0	0%
Chromium, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	n.d.	1,071(1), 139(2)	0	0%
Chromium, Total (ug/l)	10	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Copper, Dissolved (ug/l)	2	6	-----	n.d.	n.d.	4	28(1), 17(2),	0	0%
Copper, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	1,300(3)	0	0%
Hardness, Dissolved (mg/l)	1	5	223	216	211	239	-----	-----	-----
Iron, Dissolved (ug/l)	40	9	-----	n.d.	n.d.	20	-----	-----	-----
Iron, Total (ug/l)	40	15	78	74	30	152	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	148(1), 5.8(2)	0	0%
Lead, Total (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Manganese, Dissolved (ug/l)	2	16	----	2	n.d.	10	-----	-----	-----
Manganese, Total (ug/l)	2	16	18	20	n.d.	30	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	6	-----	n.d.	n.d.	n.d.	1.4(1)	0	0%
Mercury, Total (ug/l)	0.05	6	-----	n.d.	n.d.	n.d.	0.77(2), 0.05(3)	0	0%
Nickel, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	n.d.	898(1), 100(2)	0	0%
Nickel, Total (ug/l)	10	4	-----	n.d.	n.d.	n.d.	610(3)	0	0%
Selenium, Total (ug/l)	1	3	3	2	2	4	4.6(2), 170(3)	0	0%
Silver, Dissolved (ug/l)	1	6	-----	n.d.	n.d.	n.d.	12(1)	0	0%
Silver, Total (ug/l)	1	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	-----	-----	-----
Thallium, Total (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	0.24(3)	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	11	225(1,2)	0	0%
Zinc, Total (ug/l)	10	4	-----	n.d.	n.d.	11	7,400(3)	0	0%
Pesticide Scan (ug/l)[D]	0.05[E]	5	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected, b.d. = Criterion below detection limit.

(A) Results for iron (dissolved and total) and manganese (dissolved and total) include some monthly samples.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Acute (CMC) criterion for the protection of freshwater aquatic life.

(2) Chronic (CCC) criterion for the protection of freshwater aquatic life.

(3) Criterion for the protection of human health.

Note: Some of South Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

(E) Detection limits vary by pesticide – 0.05 ug/l is a median detection limit for the pesticides in the pesticide scan.

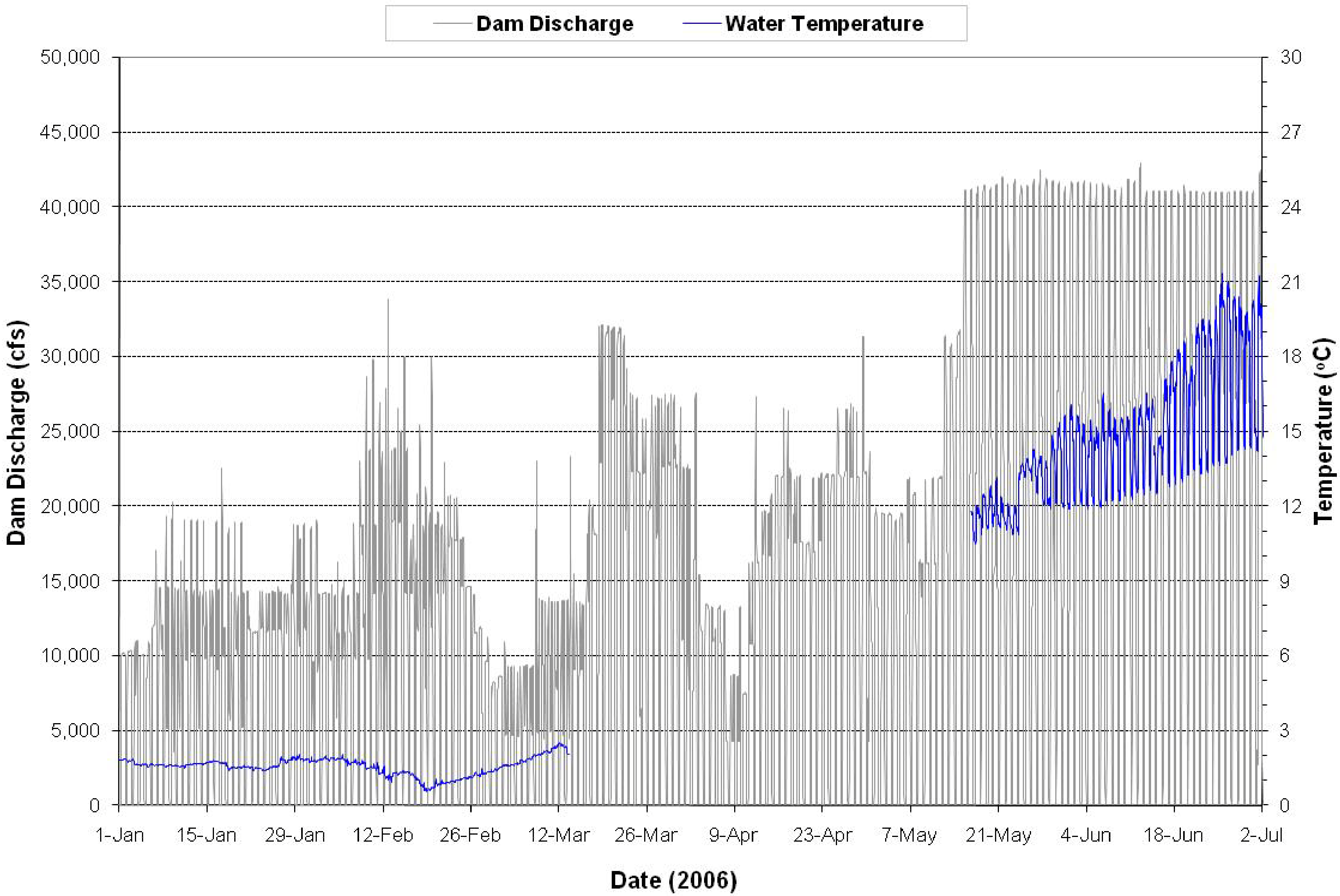

Plate 323. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2006.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

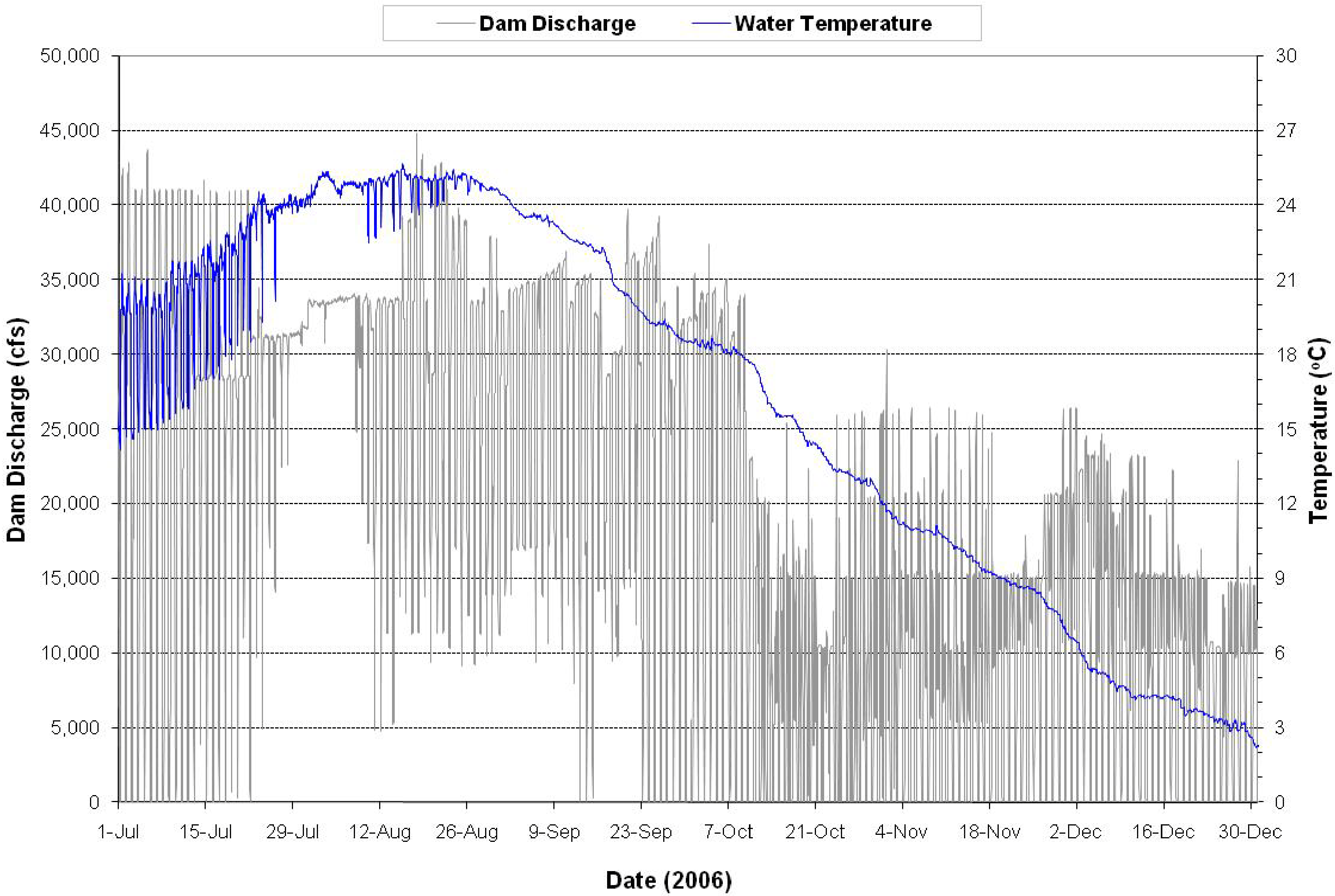

Plate 324. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2006.

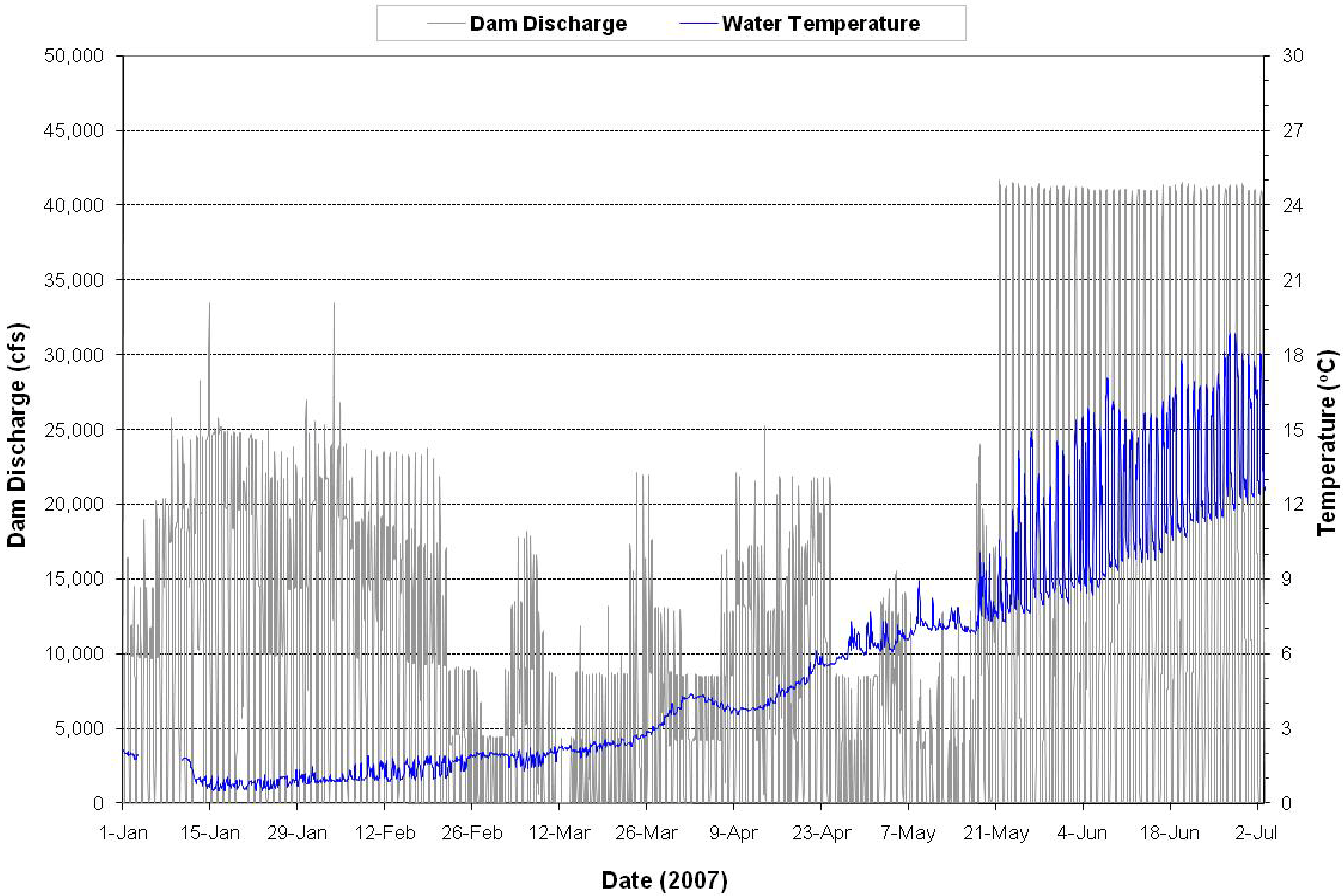

Plate 325. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2007.

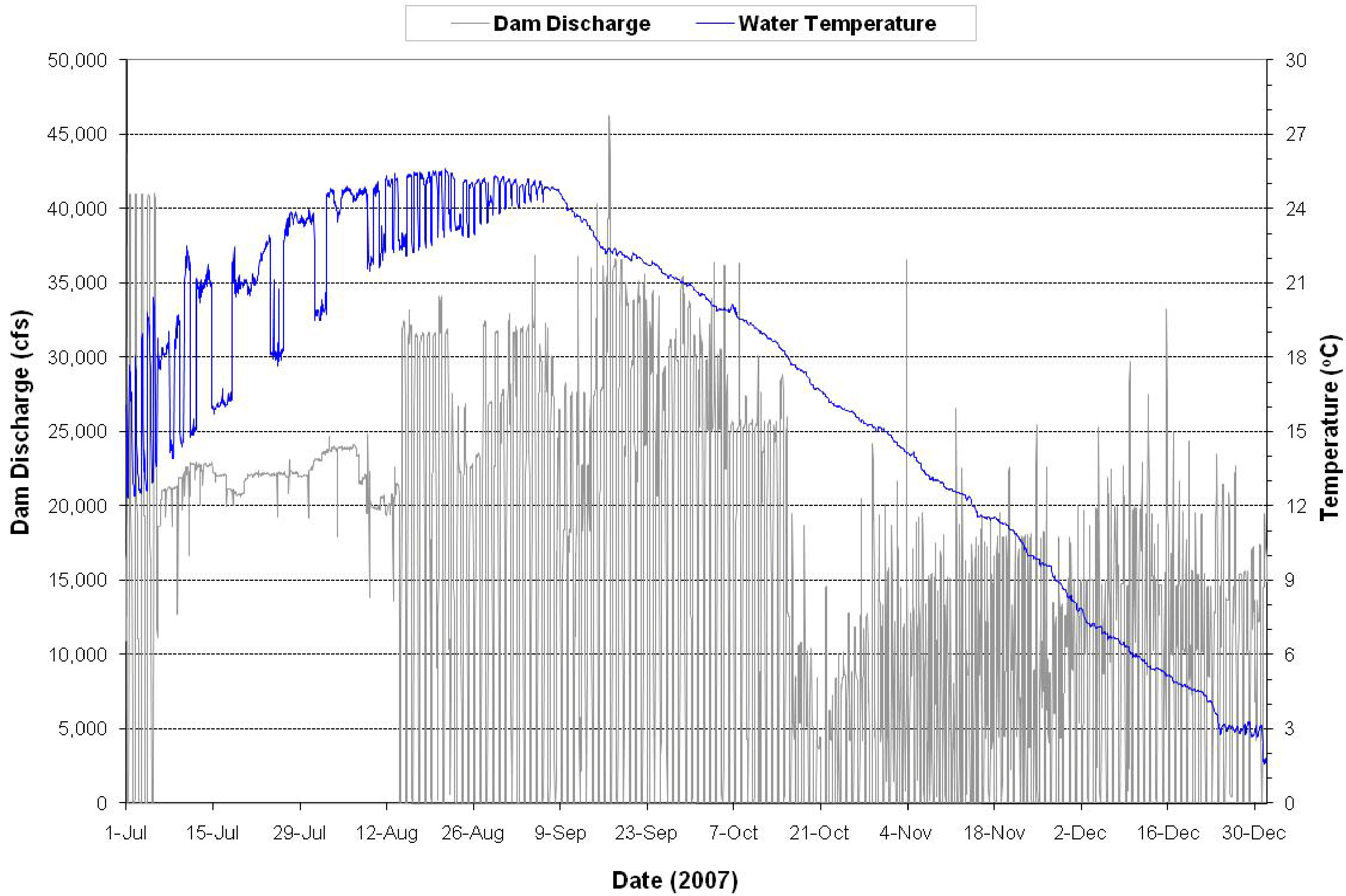

Plate 326. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2007.

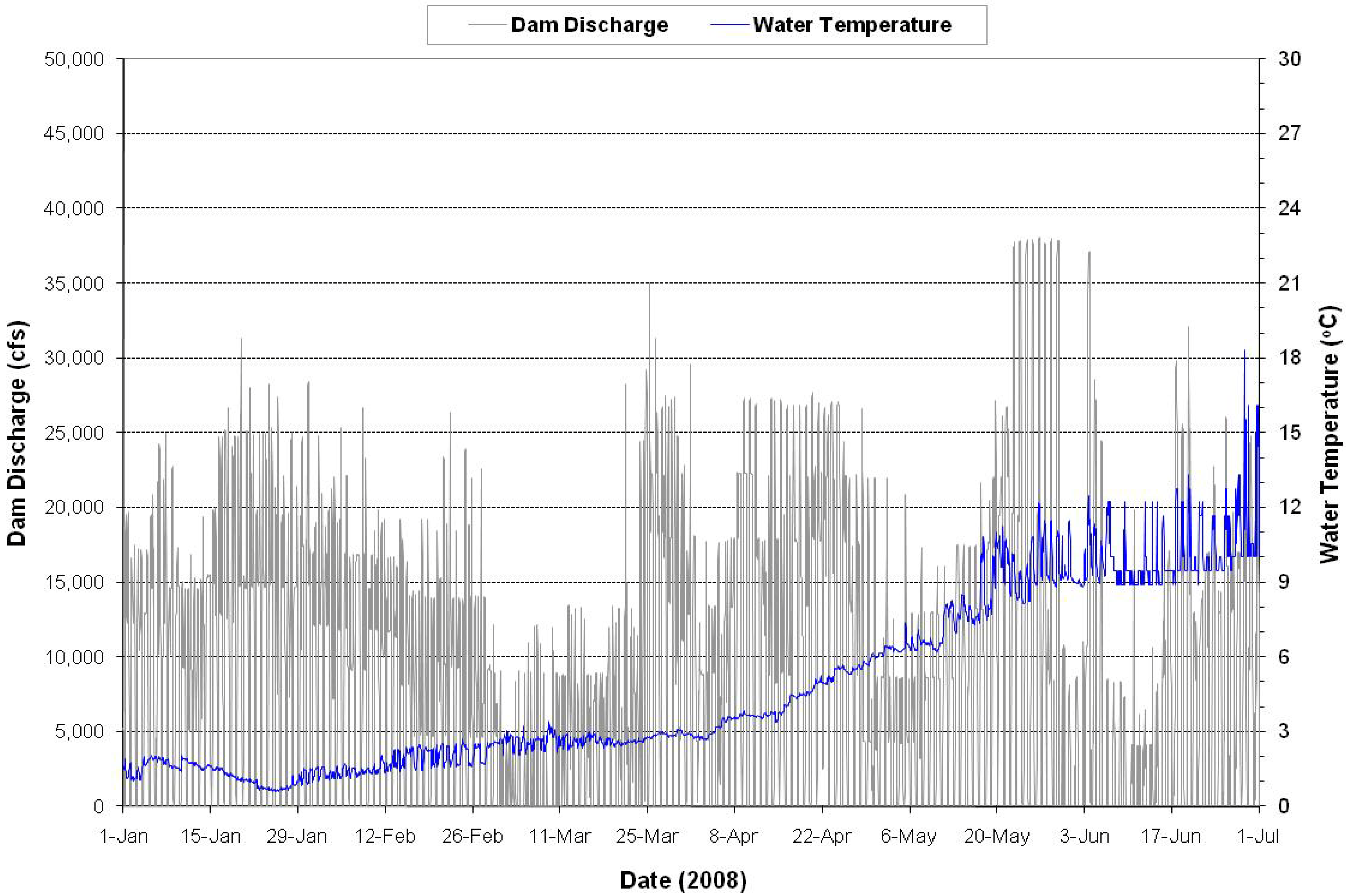

Plate 327. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2008.

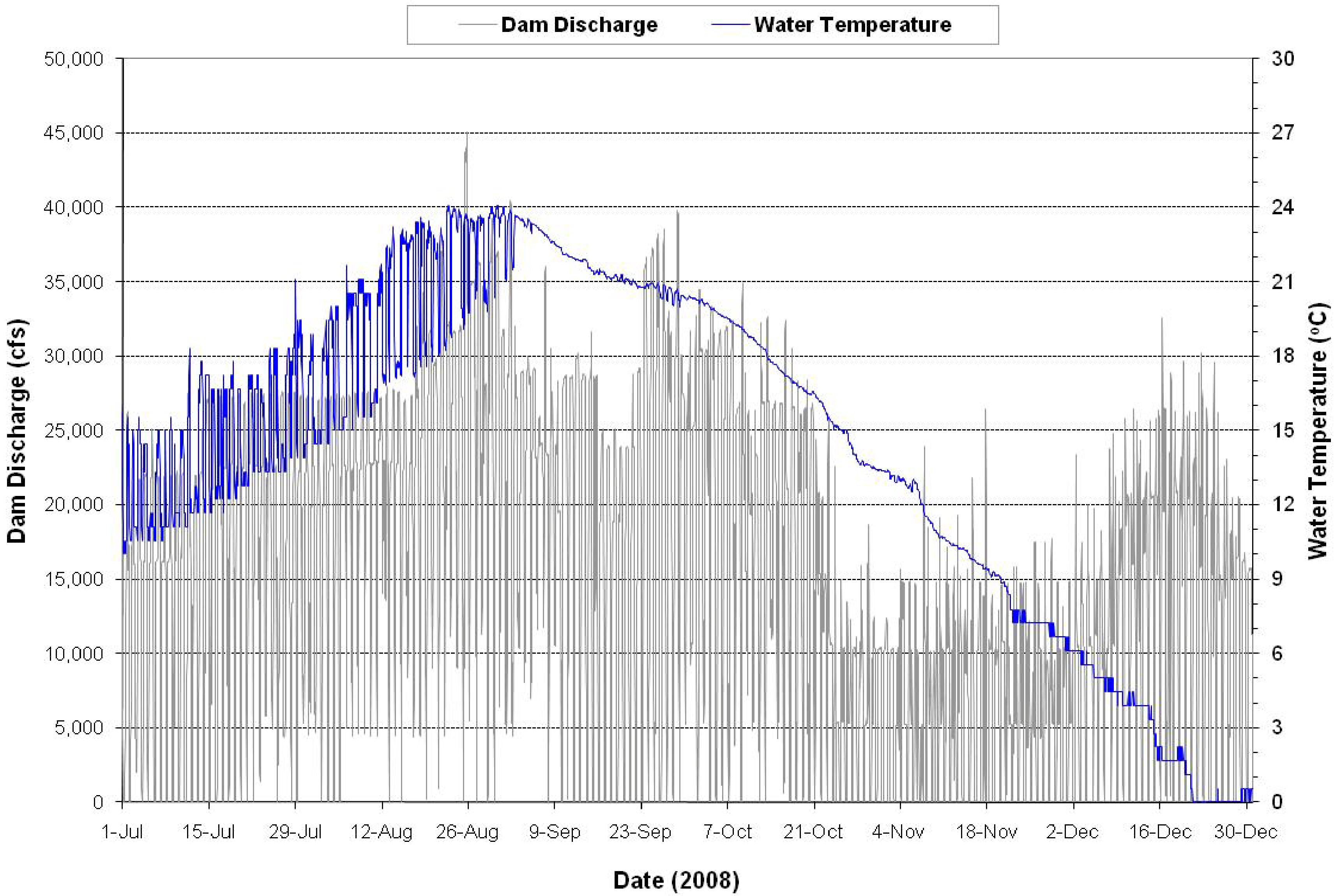

Plate 328. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2008.

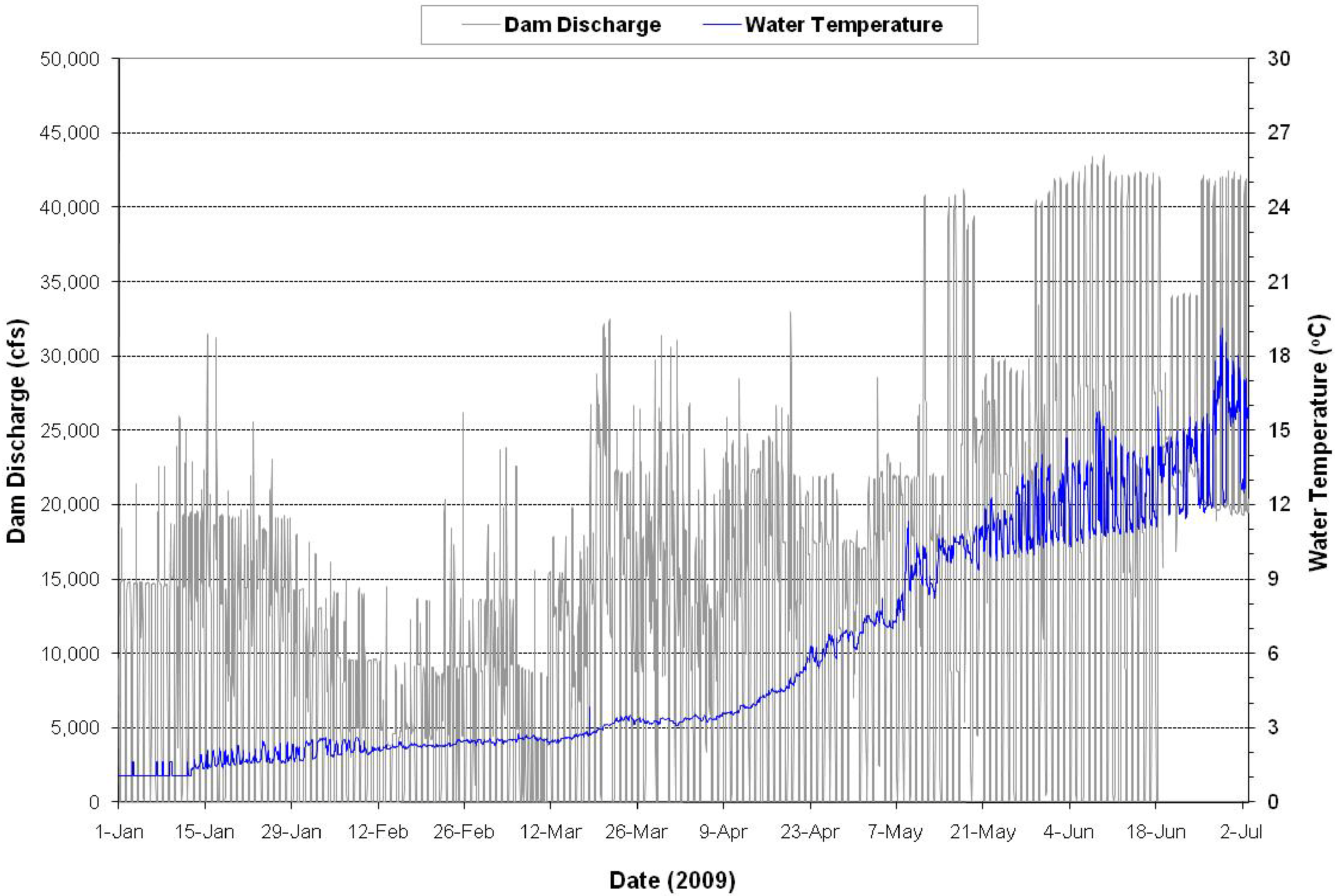

Plate 329. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2009.

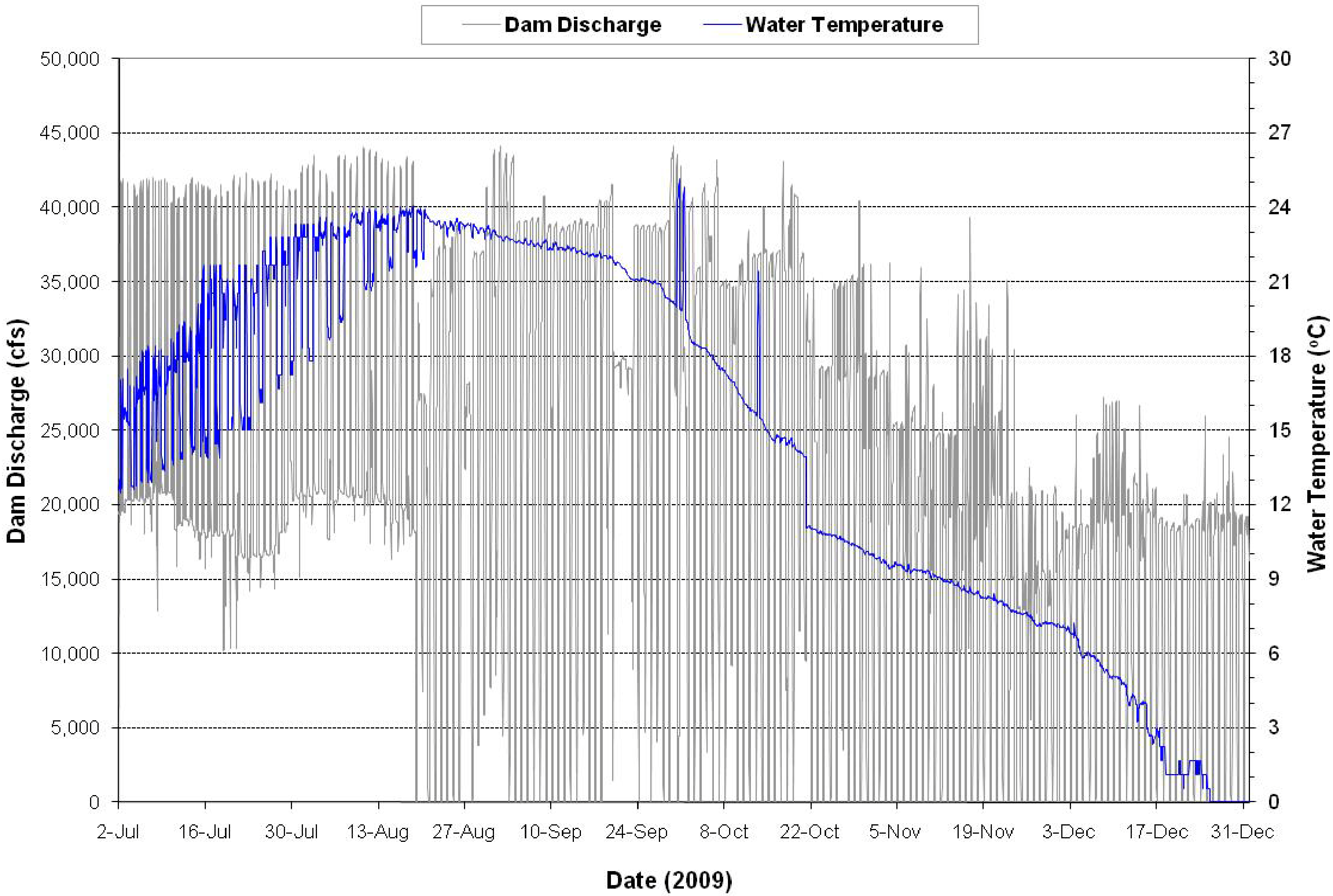

Plate 330. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2009.

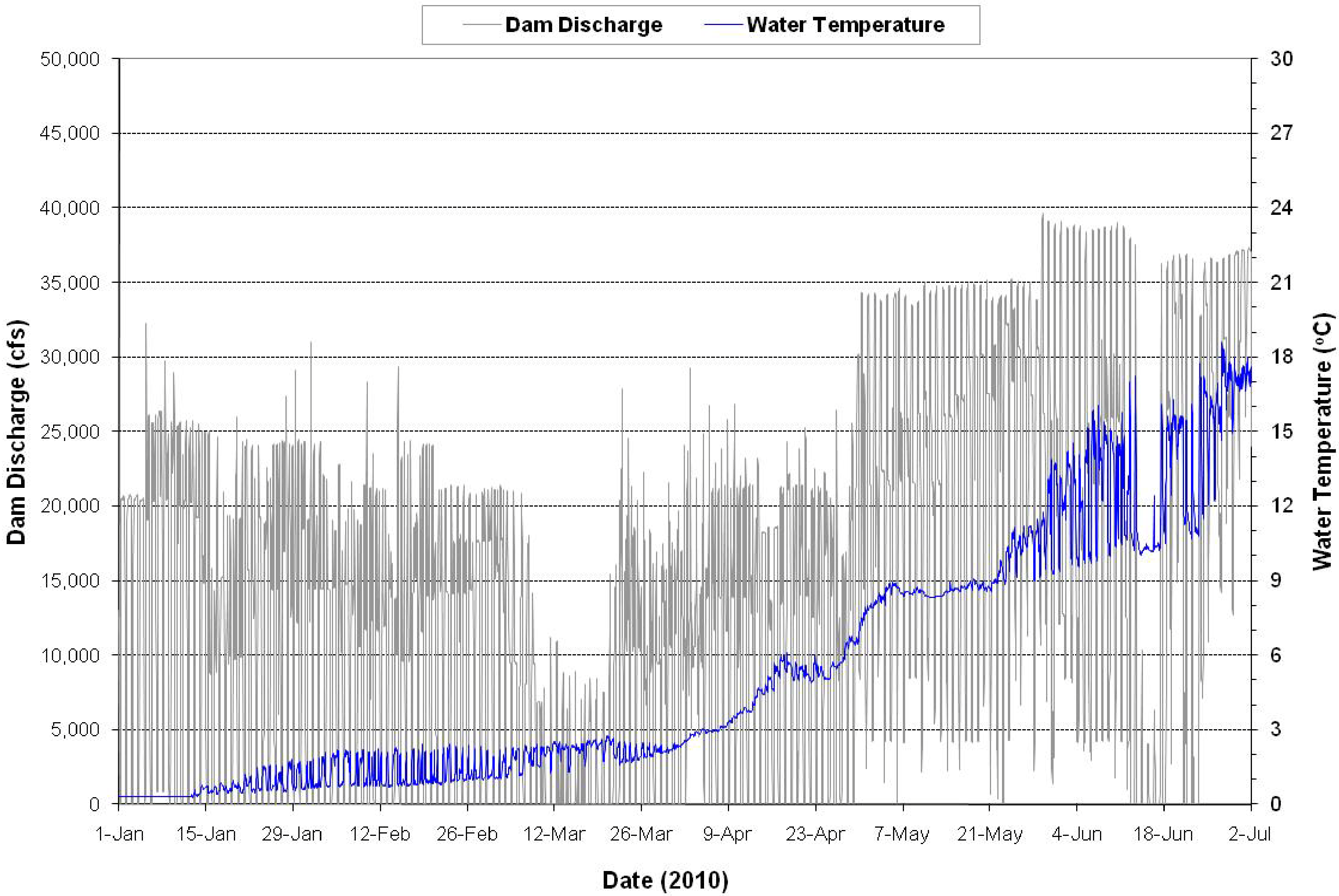

Plate 331. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 200.

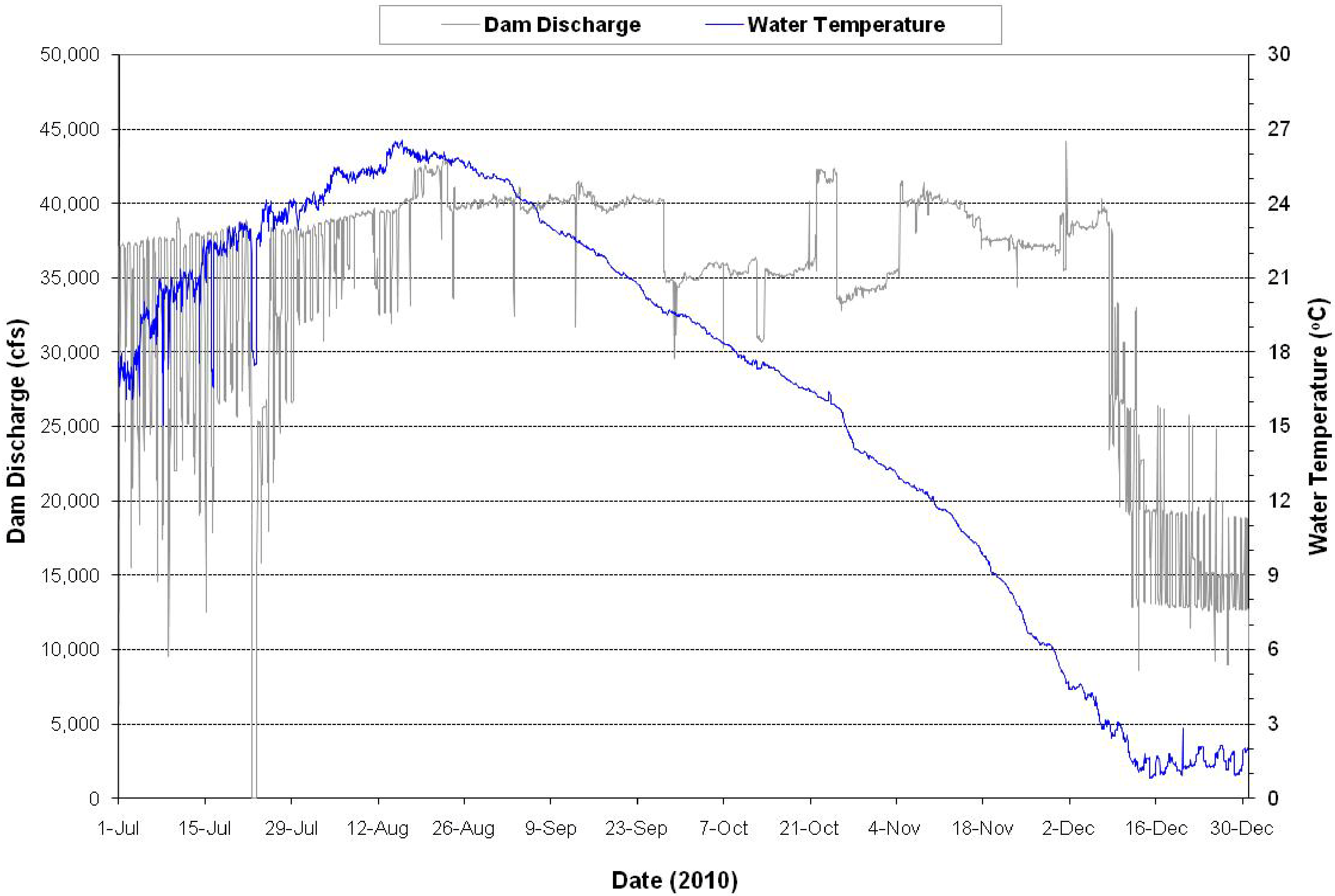

Plate 332. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2010.

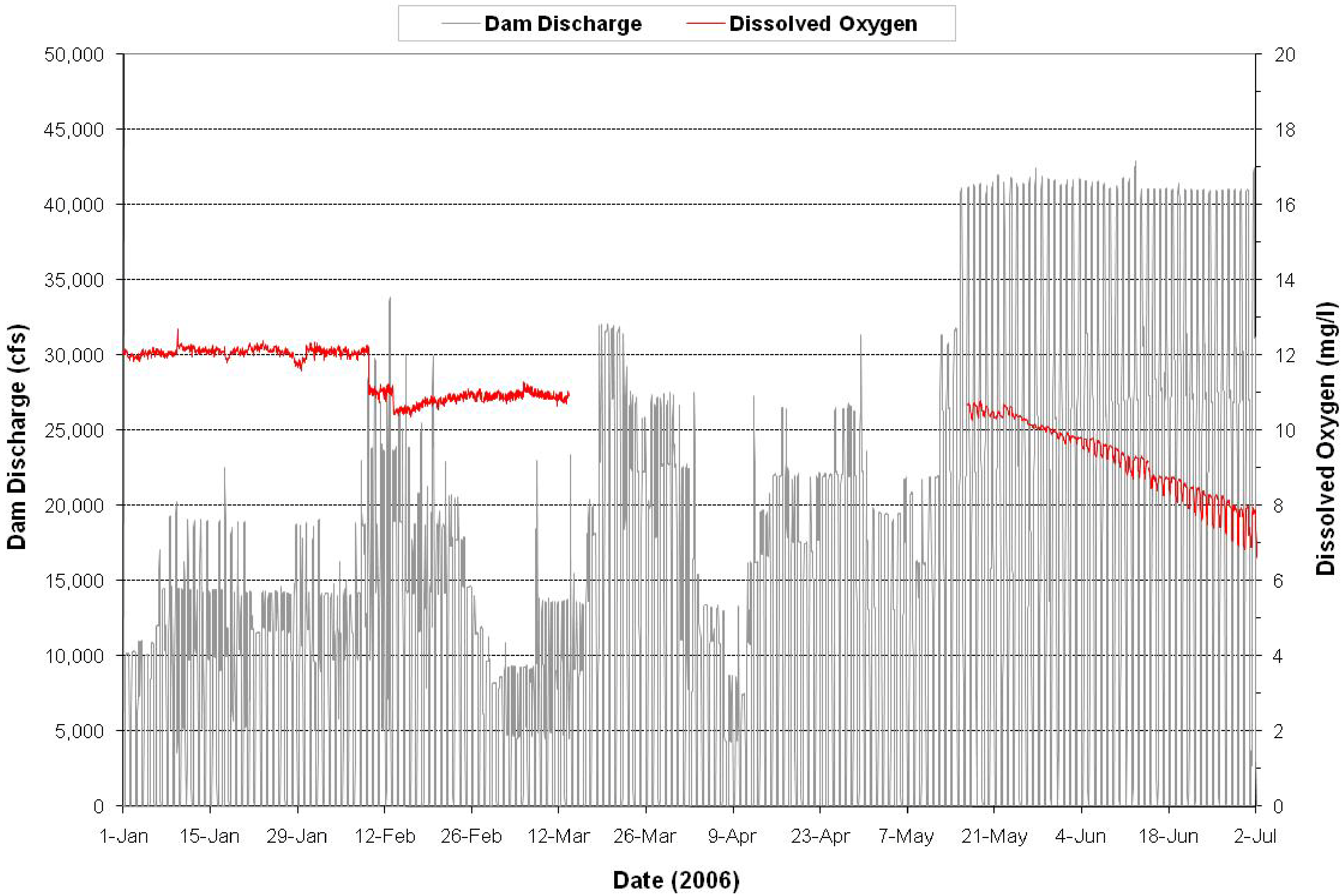

Plate 333. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2006.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

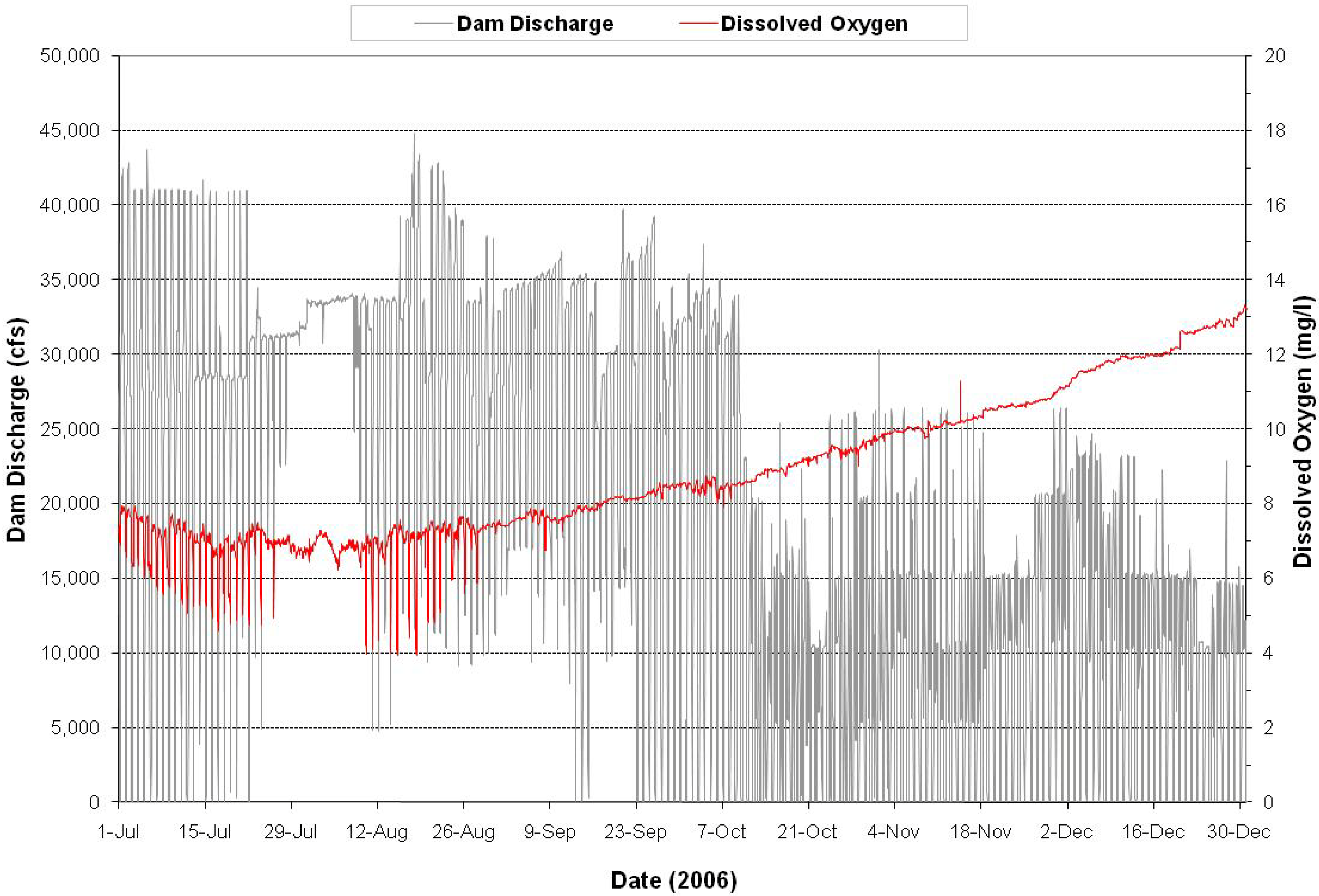

Plate 334. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2006.

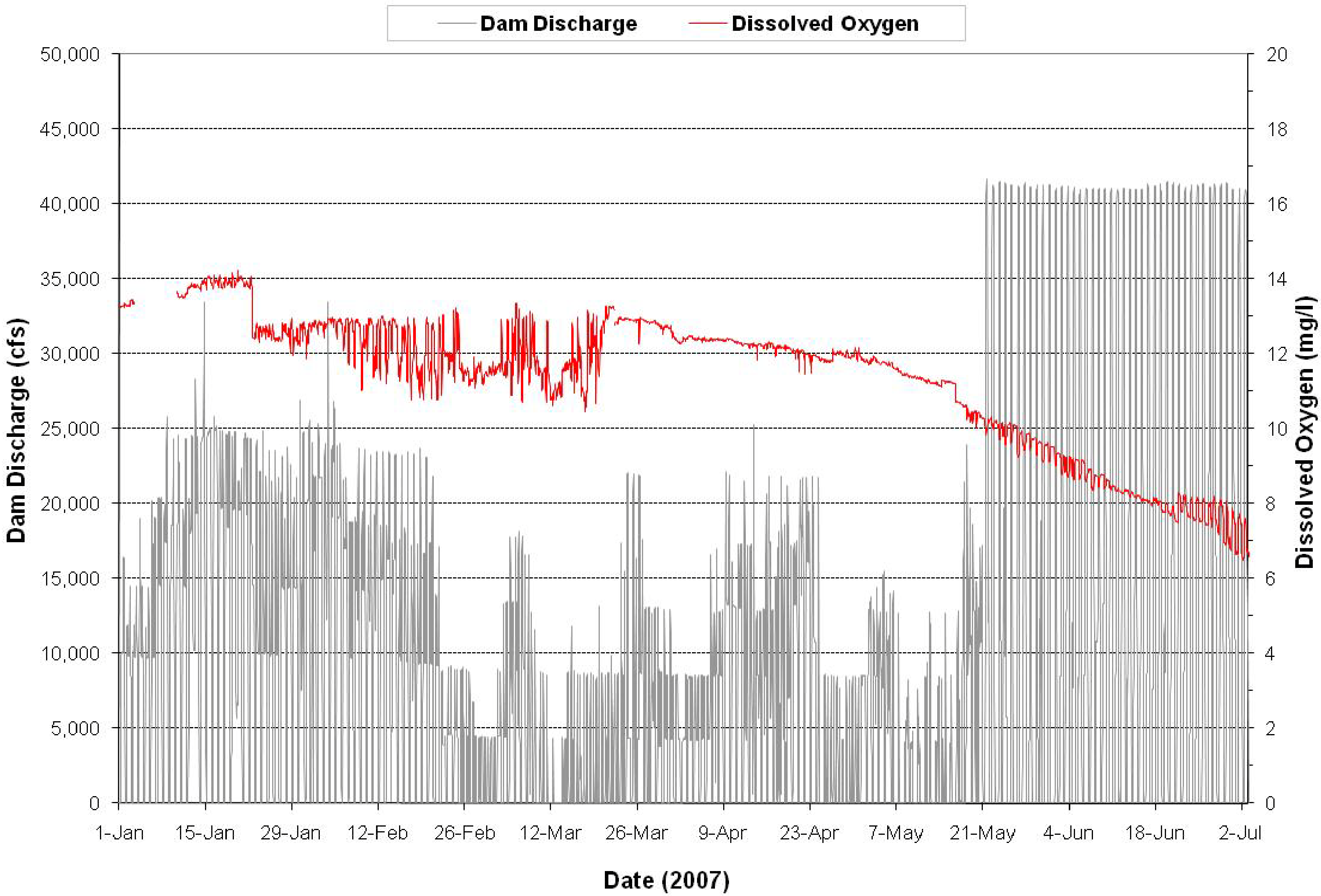

Plate 335. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2007.

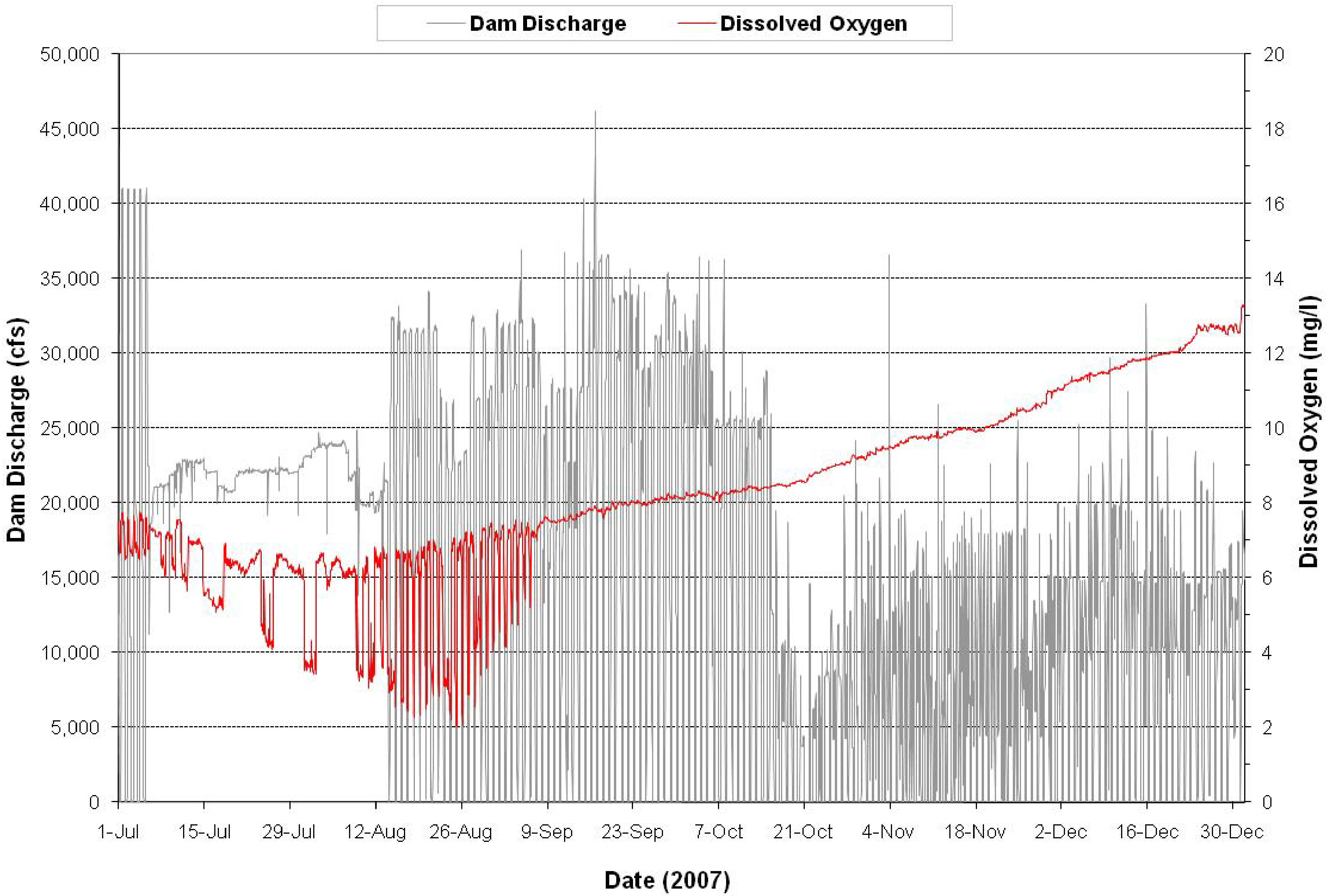

Plate 336. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2007.

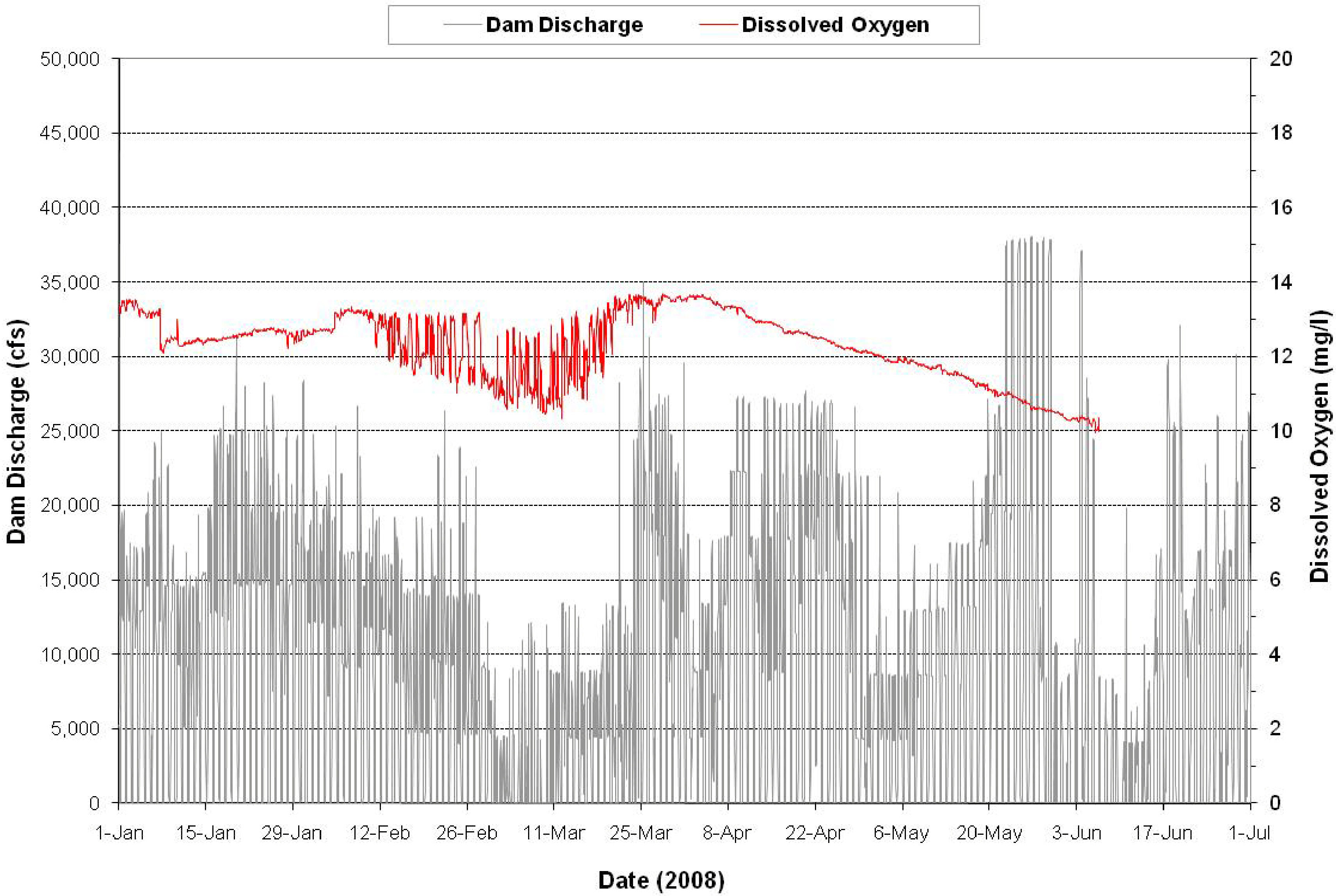

Plate 337. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2008.

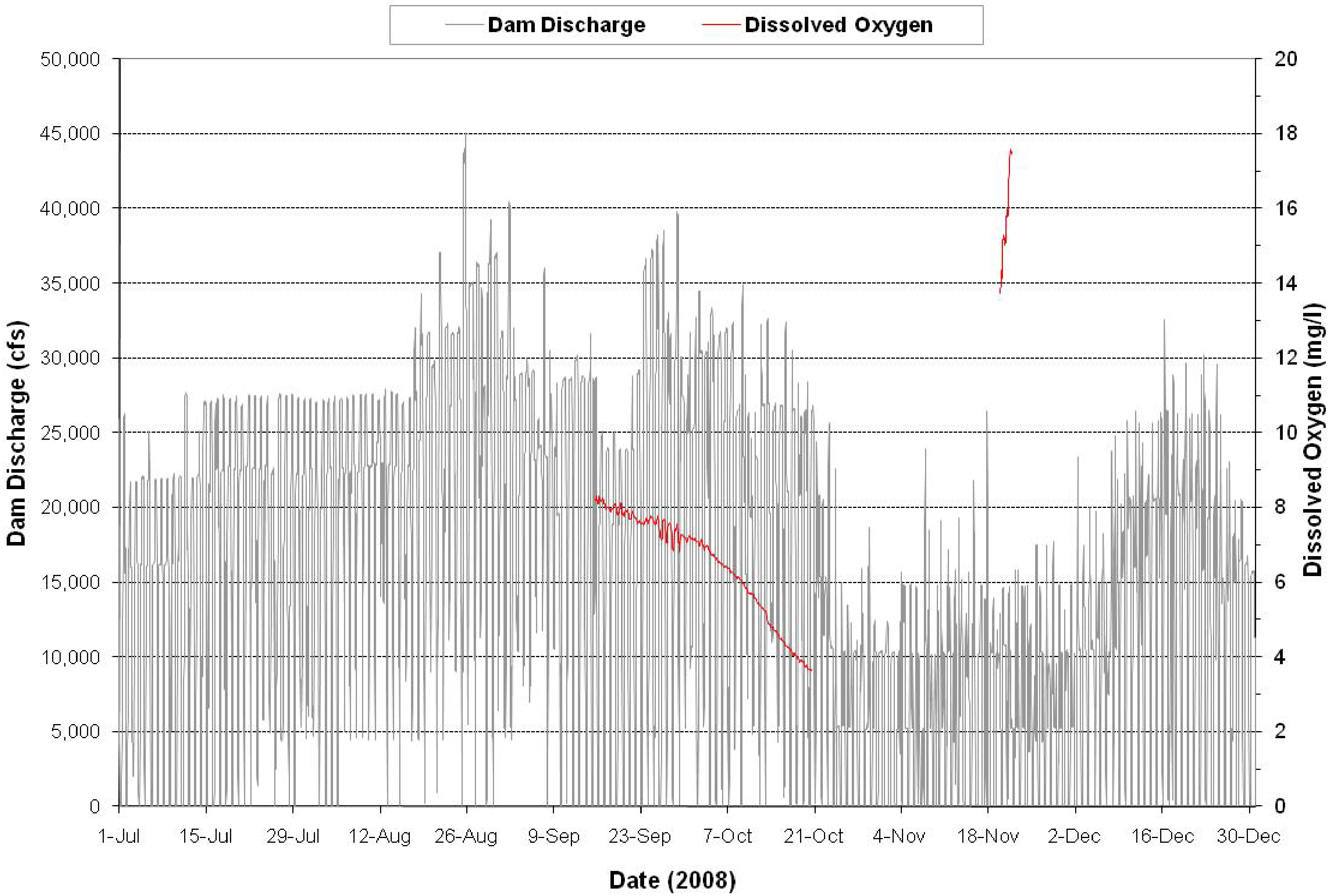

Plate 338. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2008.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

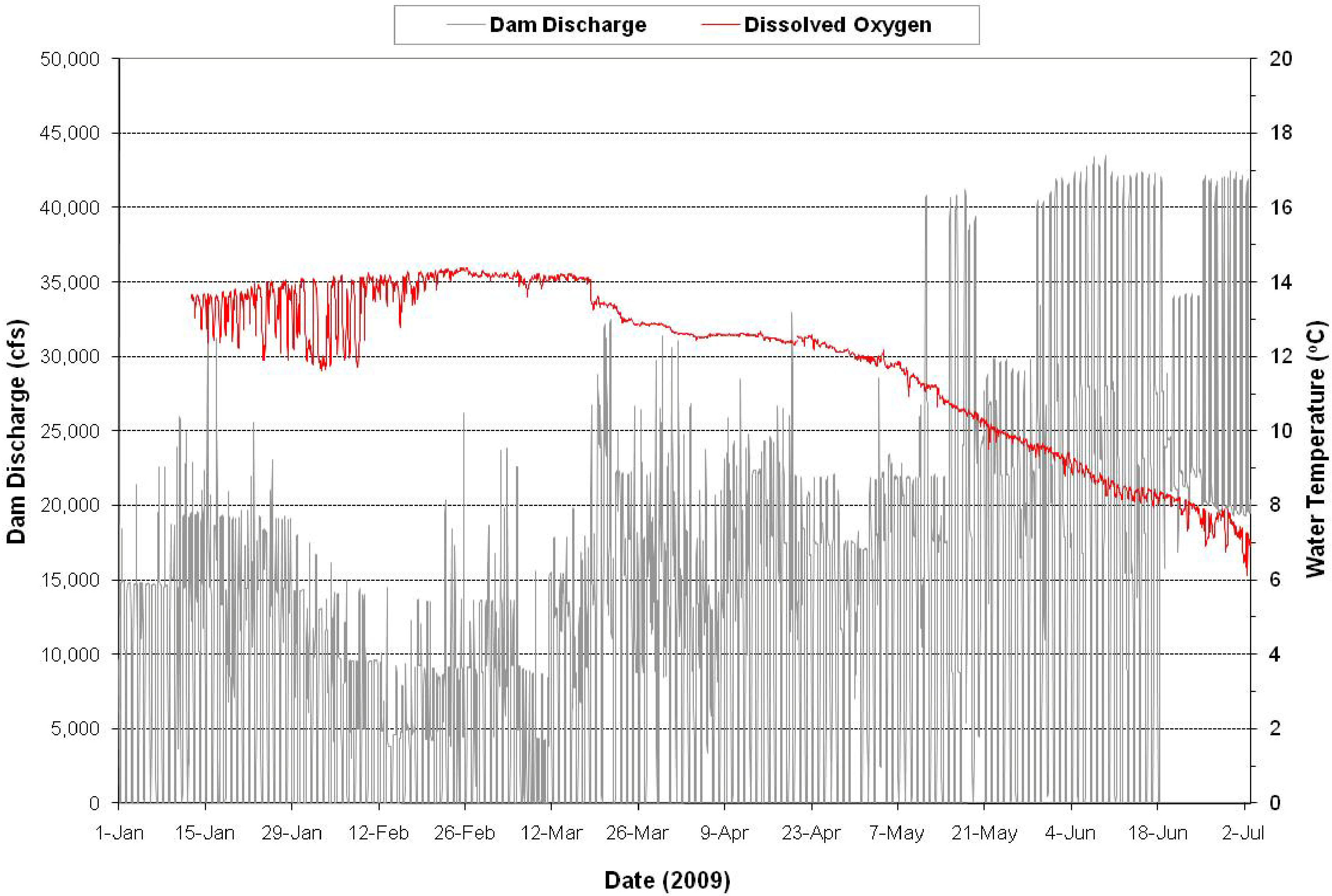

Plate 339. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2009.

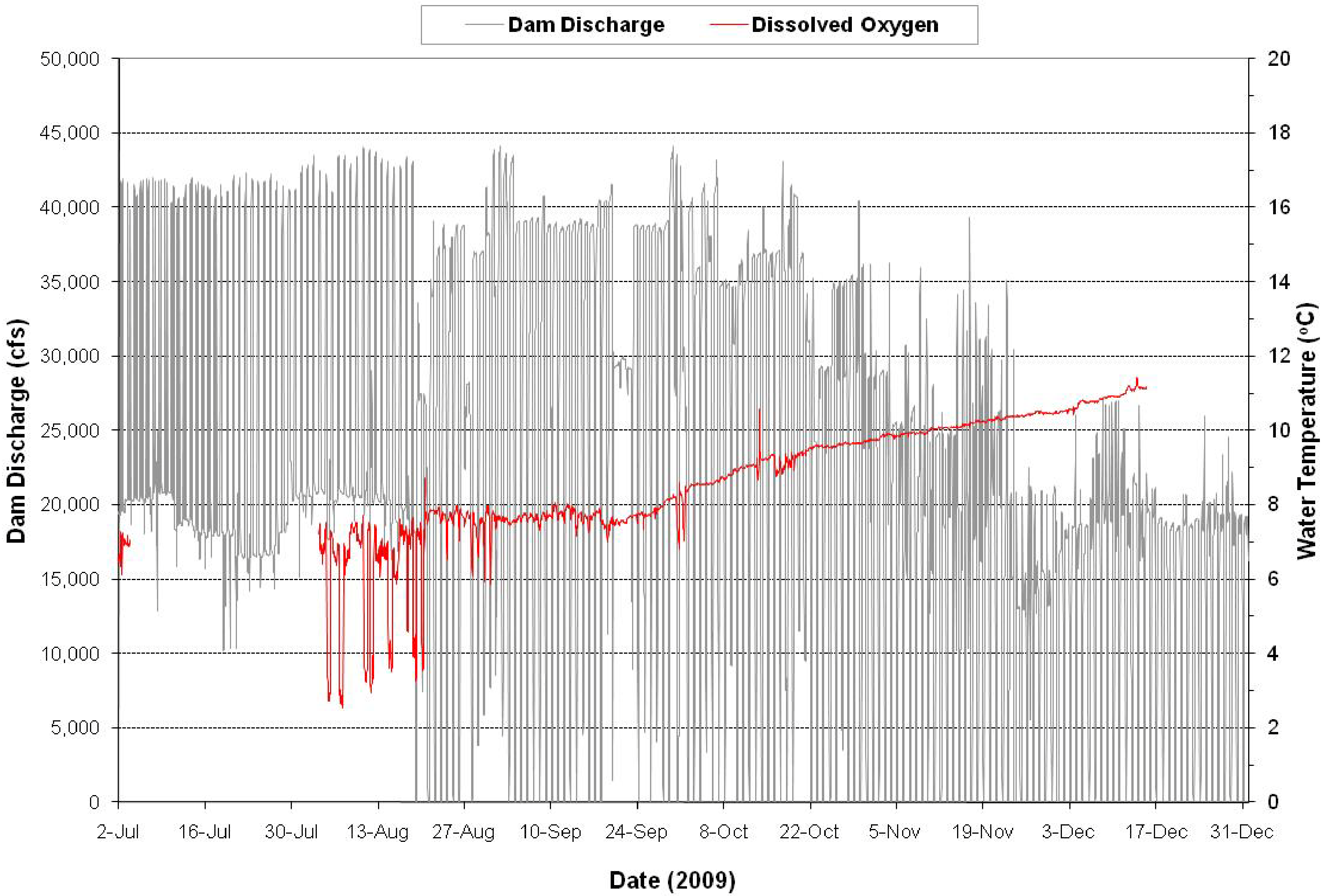

Plate 340. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2009.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

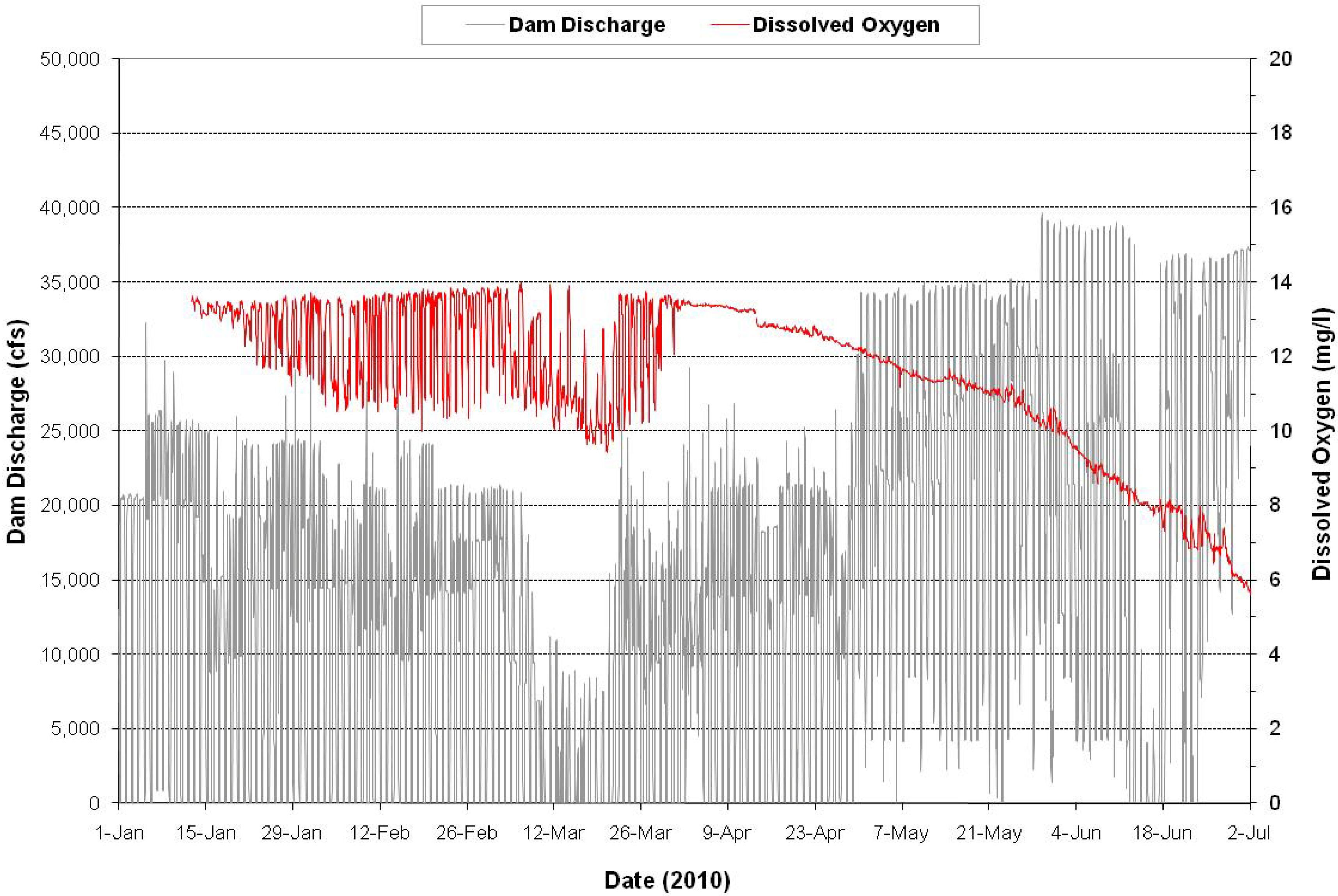

Plate 341. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2010.

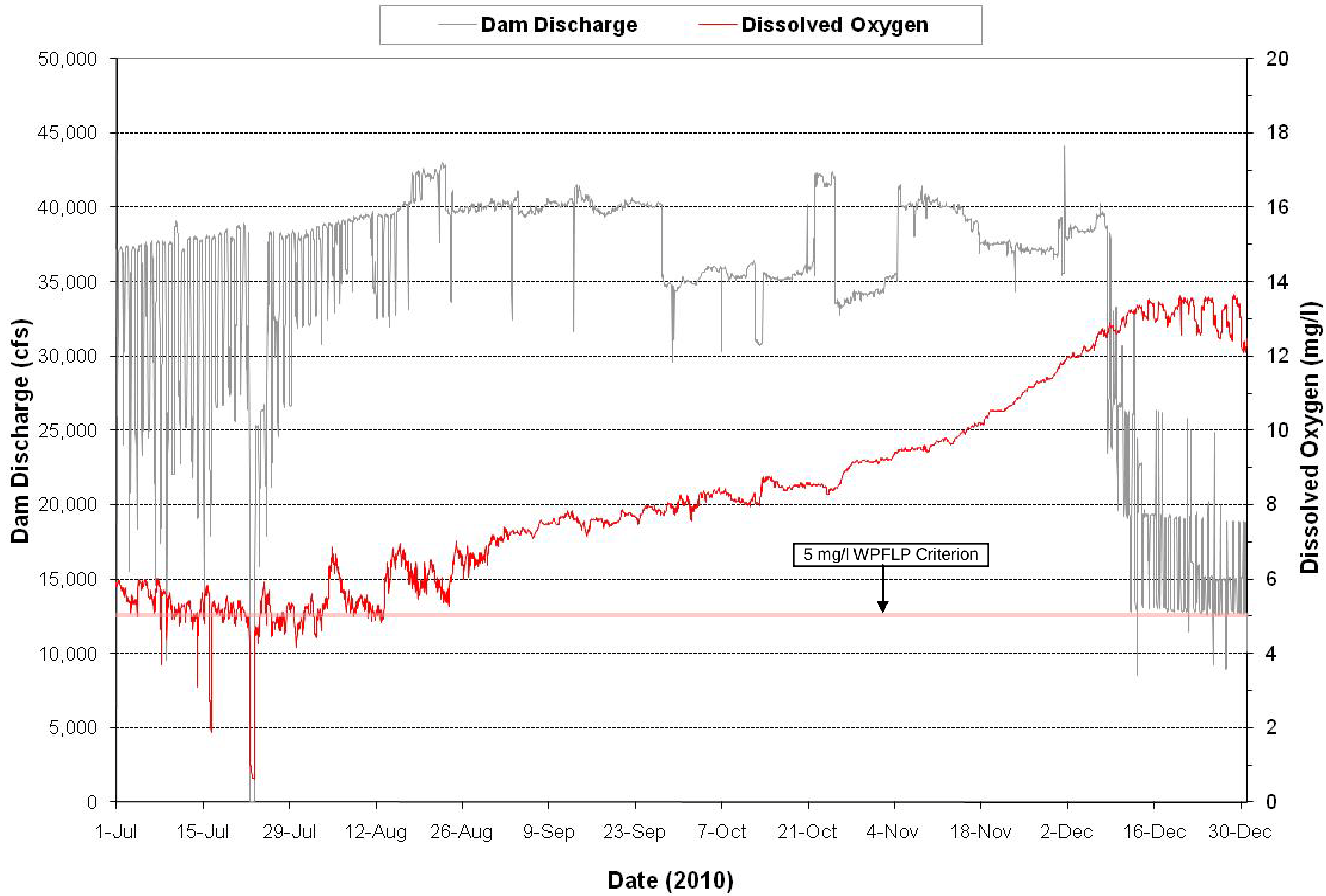

Plate 342. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2010.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

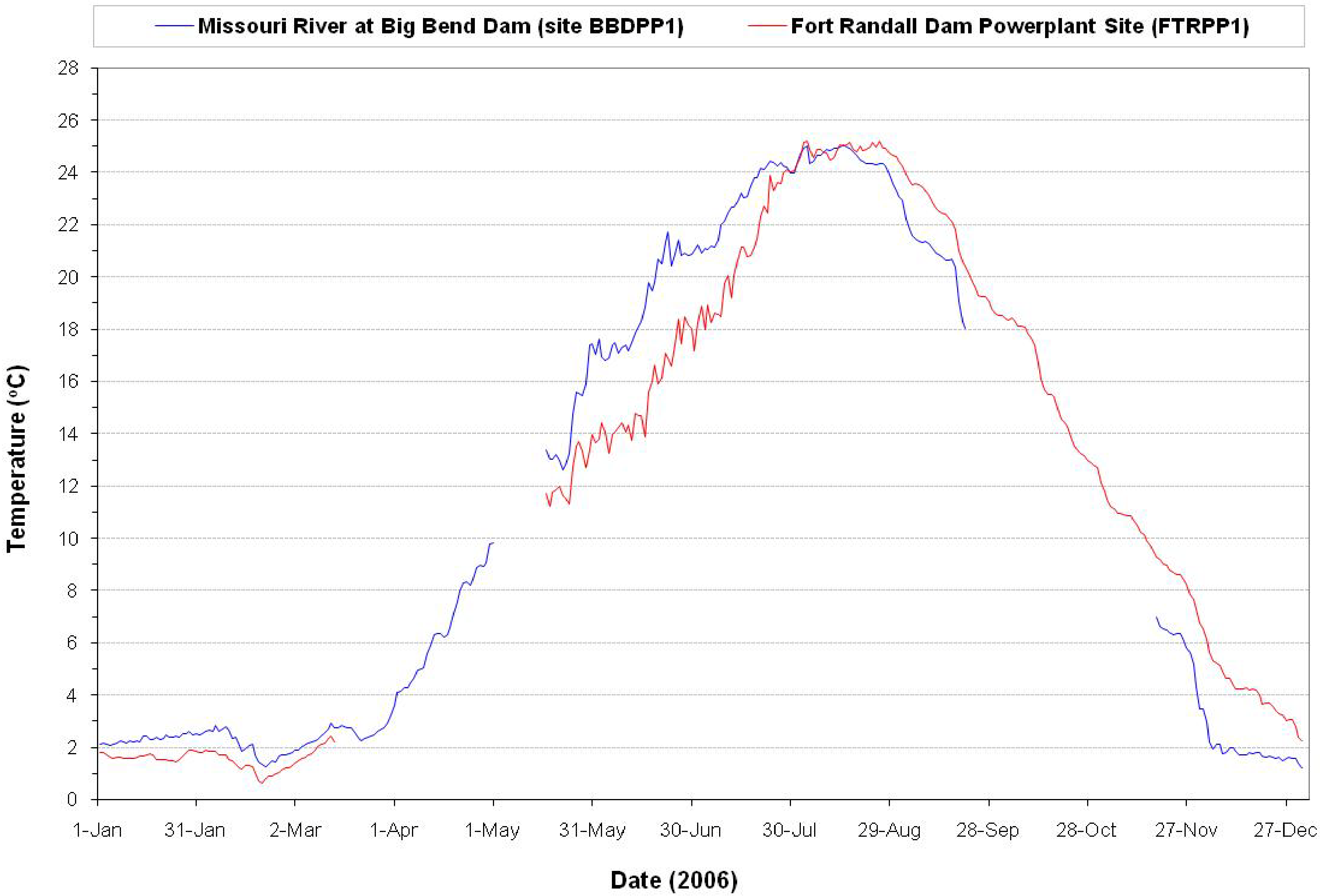

Plate 343. Mean daily water temperatures monitored at the Fort Randall Powerplant (i.e., site FTRPP1) and the Missouri River at Big Bend Dam (i.e., site BBDPP1) during 2006.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

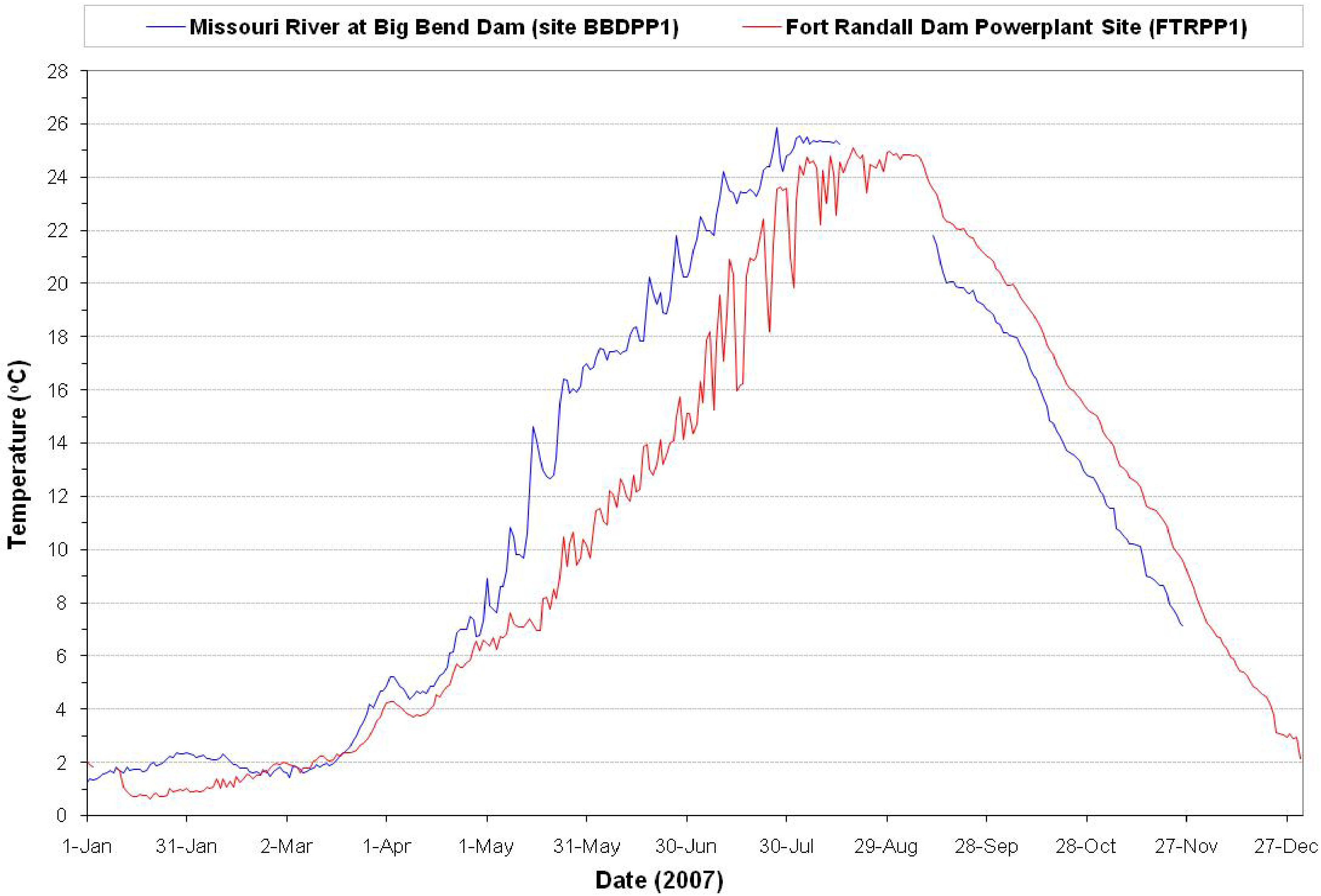

Plate 344. Mean daily water temperatures monitored at the Fort Randall Powerplant (i.e., site FTRPP1) and the Missouri River at Big Bend Dam (i.e., site BBDPP1) during 2007.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

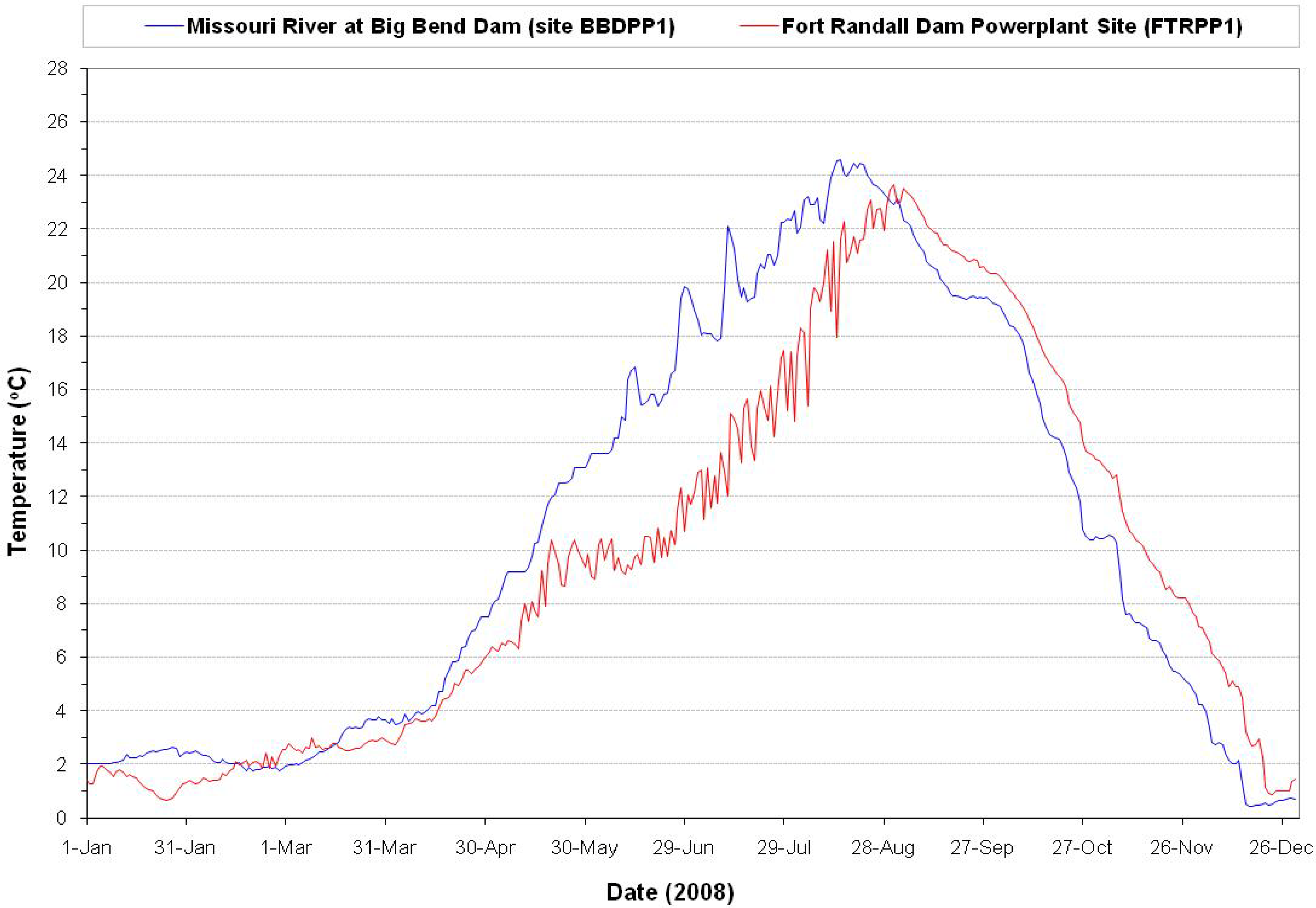

Plate 345. Mean daily water temperatures monitored at the Fort Randall Powerplant (i.e., site FTRPP1) and the Missouri River at Big Bend Dam (i.e., site BBDPP1) during 2008.

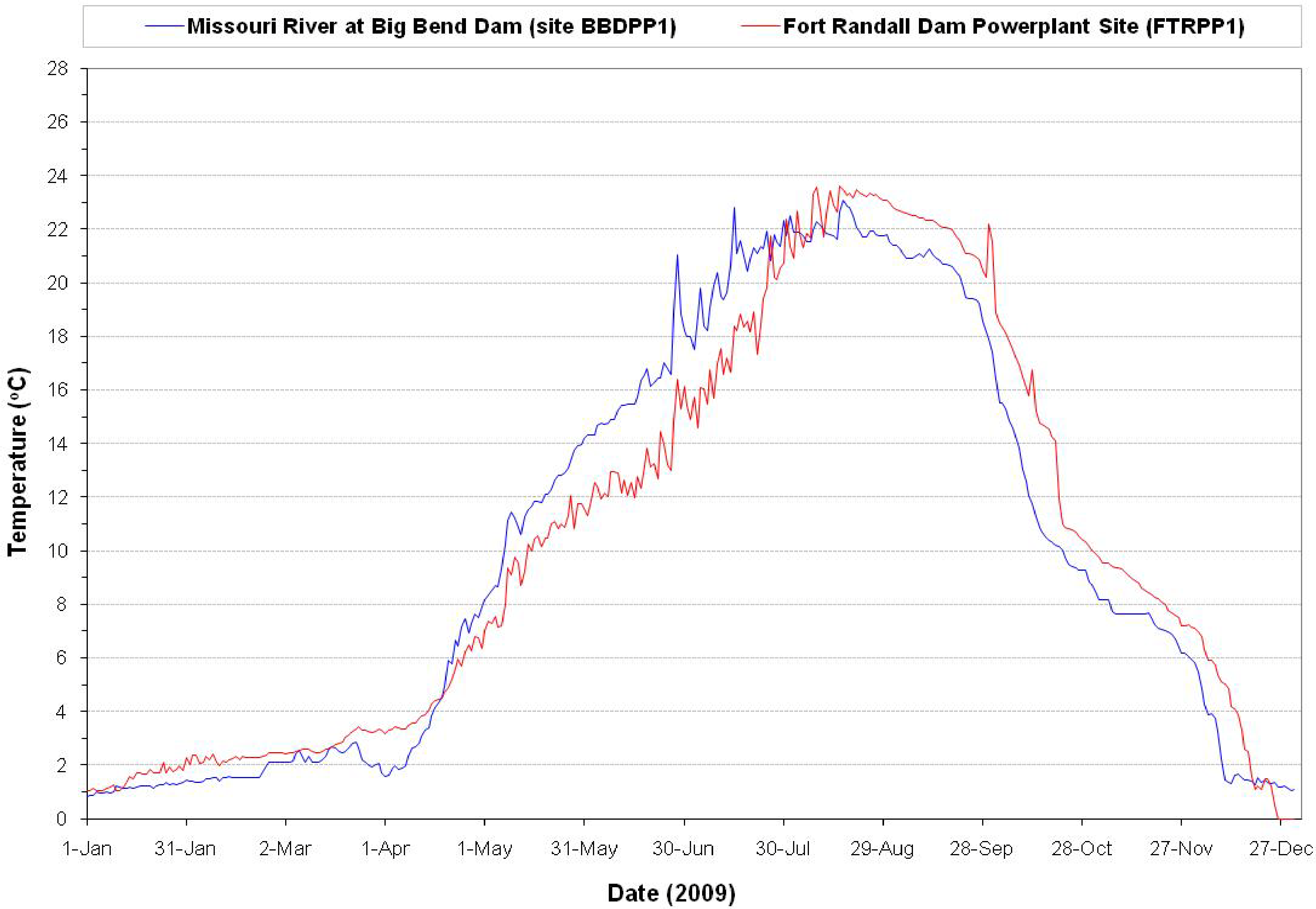

Plate 346. Mean daily water temperatures monitored at the Fort Randall Powerplant (i.e., site FTRPP1) and the Missouri River at Big Bend Dam (i.e., site BBDPP1) during 2009.

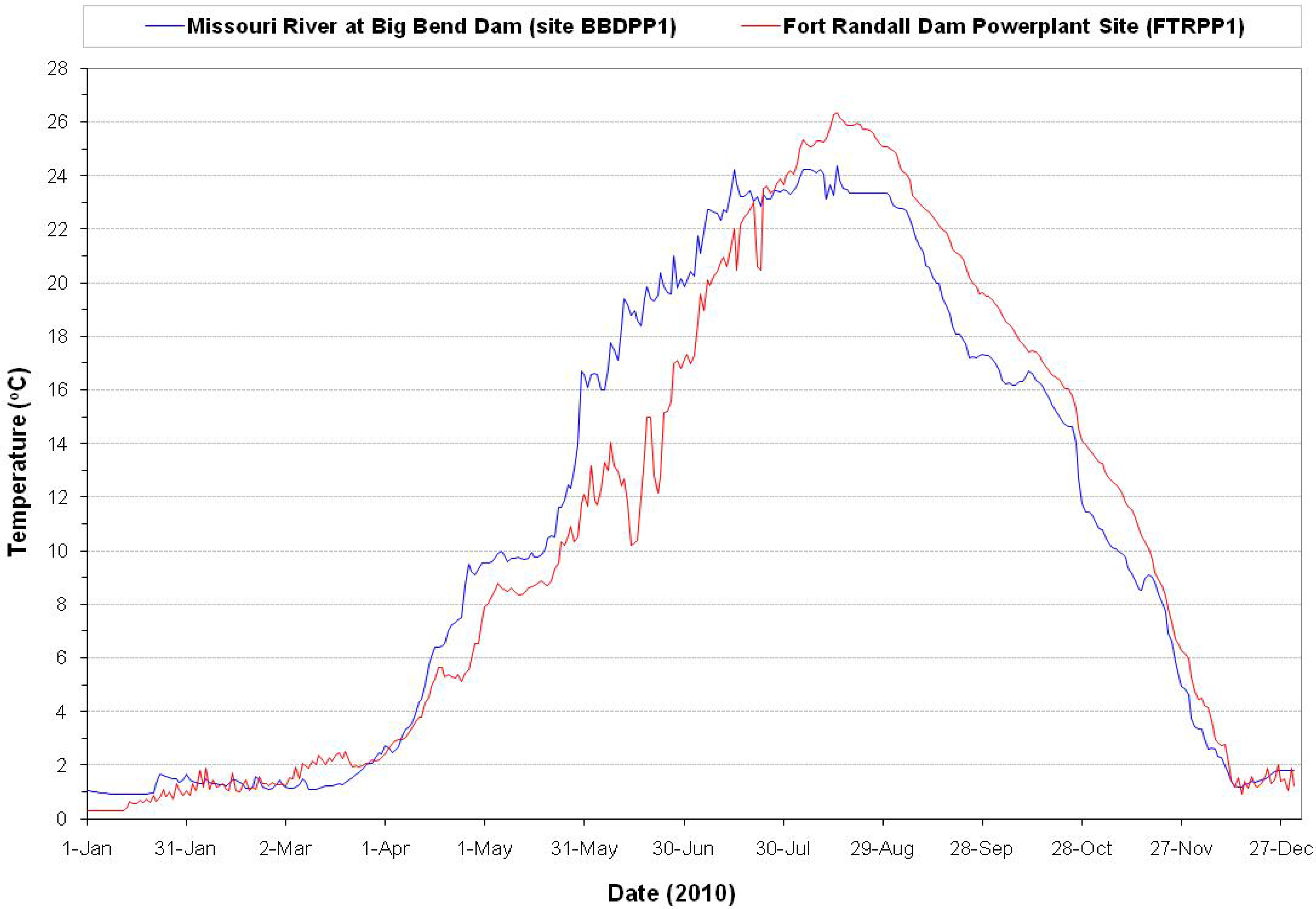

Plate 347. Mean daily water temperatures monitored at the Fort Randall Powerplant (i.e., site FTRPP1) and the Missouri River at Big Bend Dam (i.e., site BBDPP1) during 2010.

Plate 348. Summary of water quality conditions monitored in the Missouri River at the Fort Randall Dam tailwaters (i.e., site FTRRRTW1) during the 5-year period of 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[(A)]	No. of Obs.	Mean[(B)]	Median	Min.	Max.	State WQS Criteria[(C)]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	72	20,579	19,096	0	44,250	-----	-----	-----
Water Temperature (°C)	0.1	72	11.9	11.5	0.5	26.2	27[(1,4)]	0	0%
Dissolved Oxygen (mg/l)	0.1	71	10.4	10.5	5.2	16.9	≥ 5[(1,5)]	0	0%
Dissolved Oxygen (% Sat.)	0.1	71	95.6	97.2	65.8	125.6	-----	-----	-----
pH (S.U.)	0.1	70	8.2	8.2	6.8	8.7	6.5[(1,2,5)], 9.0[(1,2,4)], 9.5[(3,4)]	0	0%
Specific Conductance (umhos/cm)	1	71	725	731	634	821	-----	-----	-----
Oxidation-Reduction Potential	1	39	369	361	201	488	-----	-----	-----
Alkalinity, Total (mg/l)	7	74	163	160	128	209	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	71	3.5	3.2	1.6	16.1	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	74	10	10	n.d.	53	-----	-----	-----
Chloride (mg/l)	1	74	13	13	8	31	438[(2,4)], 250[(2,6)]	0	0%
Color (S.U. - APHA)	1	20	6	6	n.d.	11	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	71	493	480	406	840	1,750[(2,4)], 1,000[(2,7)], 3,500[(3,4)], 2,000[(3,6)]	0	0%
Hardness, Total (mg/l)	1	15	225	230	186	251	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	74	-----	0.02	n.d.	0.58	5.7 [(1,4,7)], 1.7 [(1,6,7)]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	74	0.6	0.5	n.d.	3.2	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	73	-----	n.d.	n.d.	1.40	10[(2,4)]	0	0%
Nitrogen, Total (mg/l)	0.1	73	0.7	0.5	n.d.	4.1	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	16	-----	n.d.	n.d.	0.06	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	74	-----	0.03	n.d.	0.73	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	24	-----	n.d.	n.d.	0.05	-----	-----	-----
Suspended Solids, Total (mg/l)	4	74	-----	n.d.	n.d.	178	158[(1,4)], 90[(1,6)]	1, 1	1%, 1%
Turbidity (NTU)	1	71	8	5	n.d.	67	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	11	-----	n.d.	n.d.	50	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	12	-----	n.d.	n.d.	1.5	5.6[(10)]	0	0%
Arsenic, Dissolved (ug/l)	1	12	1	1	n.d.	3	340[(8)], 150[(9)], 0.018[(10)]	b.d.	b.d.
Barium, Dissolved (ug/l)	5	12	37	37	31	44	-----	-----	-----
Beryllium, Dissolved (ug/l)	2	12	-----	n.d.	n.d.	n.d.	4[(10)]	0	0%
Cadmium, Dissolved (ug/l)	0.2	17	-----	n.d.	n.d.	n.d.	4.5[(8)], 0.44[(9)], 5[(10)]	0	0%
Chromium, Dissolved (ug/l)	10	17	-----	n.d.	n.d.	n.d.	1,127[(8)], 147[(9)]	0	0%
Copper, Dissolved (ug/l)	2	16	-----	n.d.	n.d.	3	29[(8)], 18[(9)], 1,300[(10)]	0	0%
Iron, Dissolved (ug/l)	7	11	-----	n.d.	n.d.	152	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	12	-----	n.d.	n.d.	0.8	158[(8)], 6.2[(9)]	0	0%
Manganese, Dissolved (ug/l)	21	11	-----	n.d.	n.d.	22	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	17	-----	n.d.	n.d.	n.d.	1.7[(8)], 0.05[(9)]	0	0%
Mercury, Total (ug/l)	0.05	17	-----	n.d.	n.d.	n.d.	0.77[(9)]	0	0%
Nickel, Dissolved (ug/l)	10	17	-----	n.d.	n.d.	n.d.	947[(8)], 105[(9)], 610[(10)]	0	0%
Selenium, Total (ug/l)	1	13	-----	3	n.d.	6	-----	-----	-----
Silver, Dissolved (ug/l)	1	17	-----	n.d.	n.d.	n.d.	13.5[(8)]	0	0%
Zinc, Dissolved (ug/l)	10	17	-----	n.d.	n.d.	20	237[(8,9)], 7,400[(10)]	0	0%
Acetochlor, Total (ug/l)[(D)]	0.05	31	-----	n.d.	n.d.	n.d.			
Alachlor, Total (ug/l)[(D)]	0.05	30	-----	n.d.	n.d.	n.d.	-----	-----	-----
Atrazine, Total (ug/l)[(D)]	0.05	61	-----	n.d.	n.d.	0.6	-----	-----	-----
Metolachlor, Total (ug/l)[(D)]	0.05	61	-----	n.d.	n.d.	0.3	-----	-----	-----
Pesticide Scan (ug/l)[(E)]	0.05[(F)]	11	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of commerce and industry waters.
- (4) Daily maximum criterion (monitoring results directly comparable to criterion).
- (5) Daily minimum criterion (monitoring results directly comparable to criterion).
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (8) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (9) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (10) Criterion for the protection of human health.

Note: Some of South Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

(F) Detection limits vary by pesticide – 0.05 ug/l is a median detection limit for the pesticides in the pesticide scan.

Plate 349. Summary of water quality conditions monitored in the Missouri River near Verdel, Nebraska (i.e., site MORRR0851) at RM851 during the 5-year period of 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	63	23,315	22,132	3,012	46,433	-----	-----	-----
Water Temperature (°C)	0.1	62	14.2	14.5	0.5	26.5	27[1,2,6], 29[1,2,6]	0	0%
Dissolved Oxygen (mg/l)	0.1	61	9.9	9.6	6.7	13.7	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	61	97.5	98.3	73.3	118.8	-----	-----	-----
pH (S.U.)	0.1	61	8.3	8.3	7.6	8.7	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Specific Conductance (umhos/cm)	1	62	721	732	432	827	2,000[4]	0	0%
Oxidation-Reduction Potential	1	33	360	355	199	486	-----	-----	-----
Alkalinity, Total (mg/l)	7	63	160	158	118	220	-----	0	0%
Carbon, Total Organic (mg/l)	0.05	61	3.6	3.2	1.6	12.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	63	11	11	n.d.	47	-----	-----	-----
Chloride (mg/l)	1	63	12	13	5	31	438[3,6], 250[3,8]	0	0%
Color (S.U. - APHA)	1	17	7	7	n.d.	13	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	61	490	484	310	780	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	0	0%
Hardness, Total (mg/l)	1	14	222	221	167	245	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	63	-----	0.03	n.d.	0.41	4.7[1,6,9], 1.4[1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	63	0.6	0.4	n.d.	3.4	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	63	-----	n.d.	n.d.	0.50	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/l)	0.1	63	0.6	0.5	n.d.	3.9	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	19	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	63	0.06	0.03	n.d.	0.75	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	25	-----	n.d.	n.d.	0.05	-----	-----	-----
Suspended Solids, Total (mg/l)	4	63	-----	7	n.d.	230	158[1,6], 90[1,8]	1, 1	2%, 2%
Turbidity (NTU)	1	61	13	7	0	129	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	10	-----	n.d.	n.d.	n.d.	750[10], 87[11], 200[12]	0	0%
Antimony, Dissolved (ug/l)	0.5	11	-----	n.d.	n.d.	2.0	88[10], 30[11], 6[12]	0	0%
Arsenic, Dissolved (ug/l)	1	12	2	2	n.d.	4	340[10], 16.7[11], 10[12]	0	0%
Barium, Dissolved (ug/l)	5	11	37	37	31	43	2,000[11]	0	0%
Beryllium, Dissolved (ug/l)	2	11	-----	n.d.	n.d.	n.d.	130[10], 5.3[11], 4[12]	0	0%
Cadmium, Dissolved (ug/l)	0.2	14	-----	n.d.	n.d.	1.0	4.4[10], 0.43[11], 5[12]	0, 1, 0	0%, 7%, 0%
Chromium, Dissolved (ug/l)	10	15	-----	n.d.	n.d.	n.d.	1,091[10], 142[11], 100[12]	0	0%
Copper, Dissolved (ug/l)	2	15	-----	n.d.	n.d.	4	28[10], 18[11], 1,000[12]	0	0%
Iron, Dissolved (ug/l)	7	14	-----	n.d.	n.d.	100	1,000[11]	0	0%
Lead, Dissolved (ug/l)	0.5	14	-----	n.d.	n.d.	0.8	151[10], 5.9[11], 15[12]	0	0%
Manganese, Dissolved (ug/l)	2	14	-----	n.d.	n.d.	40	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	15	-----	n.d.	n.d.	n.d.	1.4[10]	0	0%
Mercury, Total (ug/l)	0.05	15	-----	n.d.	n.d.	n.d.	0.77[11], 2[12]	0	0%
Nickel, Dissolved (ug/l)	10	15	-----	n.d.	n.d.	10	916[10], 102[11], 100[12]	0	0%
Selenium, Total (ug/l)	1	11	2	2	1	4	20[4,10], 5[11], 50[12]	0	0%
Silver, Dissolved (ug/l)	1	15	-----	n.d.	n.d.	n.d.	13[10], 100[12]	0	0%
Thallium, Dissolved (ug/l)	0.5	11	-----	n.d.	n.d.	n.d.	1,400[10], 6.3[11], 2[12]	0	0%
Zinc, Dissolved (ug/l)	5	15	-----	n.d.	n.d.	5	229[10,11], 5,000[12]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	25	-----	n.d.	n.d.	0.1	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	28	-----	n.d.	n.d.	n.d.	760[10], 76[11], 2[12]	0	0%
Atrazine, Total (ug/l)[D]	0.05	53	-----	n.d.	n.d.	0.6	330[10], 12[11], 3[12]	0	0%
Metolachlor, Total (ug/l)[D]	0.05	53	-----	n.d.	n.d.	0.2	390[10], 100[11]	0	0%
Pesticide Scan (ug/l)[E]	0.05[F]	11	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
(2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
(3) Criteria for the protection of domestic water supply waters.
(4) Criteria for the protection of agricultural water supply waters.
(5) Criteria for the protection of commerce and industry waters.
(6) Daily maximum criterion (monitoring results directly comparable to criterion).
(7) Daily minimum criterion (monitoring results directly comparable to criterion).
(8) 30-day average criterion (monitoring results not directly comparable to criterion).
(9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(10) Acute (CMC) criterion for the protection of freshwater aquatic life.
(11) Chronic (CCC) criterion for the protection of freshwater aquatic life.
(12) Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

(F) Detection limits vary by pesticide – 0.05 ug/l is a median detection limit for the pesticides in the pesticide scan.

Plate 350. Summary of monthly (May through September) water quality conditions monitored in Lewis and Clark Lake near Gavins Point Dam (Site GPTLK0811A) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	25	1206.5	1206.5	1205.4	1207.7	-----	-----	-----
Water Temperature (°C)	0.1	304	20.9	21.3	9.3	26.5	27[1,2,6], 29[1,2,6]	0	0%
Dissolved Oxygen (mg/l)	0.1	304	8.4	8.4	1.4	15.1	5[1,7]	20	7%
Dissolved Oxygen (% Sat.)	0.1	304	96.7	98.2	16.7	165.4	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	273	8.7	8.5	4.1	15.1	5[1,7]	4	1%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	31	5.5	5.0	1.4	10.7	5[1,7]	16[F]	52%[F]
Specific Conductance (umhos/cm)	1	303	707	710	595	778	2,000[4]	0	0%
pH (S.U.)	0.1	292	8.4	8.5	7.8	9.0	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Turbidity (NTUs)	1	304	15	11	1	132	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	304	318	319	157	496	-----	-----	-----
Secchi Depth (in.)	1	25	37	36	18	52	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	153	155	130	170	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	46	3.6	3.4	1.8	6.1	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	48	11	12	n.d.	19	-----	-----	-----
Chloride (mg/l)	1	38	11	11	9	14	438[3,6], 250[3,8]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	200	21*	18	1	69	10[10]	159	80%
Chlorophyll *a* (ug/l) – Lab Determined	1	24	16*	15	n.d.	53	10[10]	17	71%
Color (S.U. - APHA)	1	20	8	8	4	19	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	48	467	461	386	578	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	48	-----	0.03	n.d.	0.23	3.2 [1,6,9], 0.66[1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	48	0.5	0.5	n.d.	1.6	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	48	-----	n.d.	n.d.	0.30	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/l)	0.1	48	0.6	0.5	n.d.	1.7	1[10]	3	6%
Phosphorus, Dissolved (mg/l)	0.02	48	-----	n.d.	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	48	0.05	0.04	n.d.	0.18	0.05[10]	16	33%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	48	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	48	202	201	177	235	875[3,6], 500[3,8]	0	0%
Suspended Solids, Total (mg/l)	4	48	9	7	n.d.	82	158[1,6], 90[1,8]	0	0%
Microcystin, Total (ug/l)	0.2	24	-----	n.d.	n.d.	14	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
(2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
(3) Criteria for the protection of domestic water supply waters.
(4) Criteria for the protection of agricultural water supply waters.
(5) Criteria for the protection of commerce and industry waters.
(6) Daily maximum criterion (monitoring results directly comparable to criterion).
(7) Daily minimum criterion (monitoring results directly comparable to criterion).
(8) 30-day average criterion (monitoring results not directly comparable to criterion).
(9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(10) Nutrient criteria – Lewis and Clark Lake has been assigned the following nutrient criteria by Nebraska for 2010 Section 303(d) and 305(b) assessment: Chlorophyll a = 10 ug/l, Total Nitrogen = 1 mg/l, and Total Phosphorus = 50 ug/l.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) According to South Dakota's beneficial use support decision criteria, dissolved oxygen levels are not considered impaired if a region exists in the depth profile (i.e., epilimnion) where the dissolved oxygen levels are ≥5 mg/l. Nebraska's dissolved oxygen criteria do not apply to the hypolimnion.

* The highlighted mean values indicate use impairment based on State of Nebraska 2010 Section 303(d) impairment assessment criteria.

Plate 351. Summary of monthly (June through September) water quality conditions monitored in Lewis and Clark Lake near the Weigand Recreation Area (site GPTLK0815DW) during the 3-year period 2008 through 2010.

Parameter	Monitoring Results(A)						Water Quality Standards Attainment		
	Detection Limit(B)	No. of Obs.	Mean(C)	Median	Min.	Max.	State WQS Criteria(D)	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	13	1206.5	1206.4	1205.5	1207.5	-----	-----	-----
Water Temperature (°C)	0.1	127	21.5	22.0	14.1	25.6	27(1,2,6), 29(1,2,6)	0	0%
Dissolved Oxygen (mg/l)	0.1	127	8.3	8.3	5.5	10.2	5(1,7)	0	0%
Dissolved Oxygen (% Sat.)	0.1	127	97.1	97.5	67.2	121.0	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)(E)	0.1	127	8.3	8.3	5.5	10.2	5(1,7)	0	0%
Hypolimnion Dissolved Oxygen (mg/l)(E)	0.1	0	-----	-----	-----	-----	5(1,7)	-----	-----
Specific Conductance (umhos/cm)	1	127	710	706	658	761	-----	-----	-----
pH (S.U.)	0.1	127	8.4	8.4	7.8	8.9	6.5(1,3,7), 9.0(1,3,6), 9.5(5,6)	0	0%
Turbidity (NTUs)	1	127	23	20	3	94	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	127	312	331	167	439	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	106	23*	17	1	85	10(8)	86	81%
Secchi Depth (in)	1	13	22	20	13	38	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
(2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
(3) Criteria for the protection of domestic water supply waters.
(4) Criteria for the protection of agricultural water supply waters.
(5) Criteria for the protection of commerce and industry waters.
(6) Daily maximum criterion (monitoring results directly comparable to criterion).
(7) Daily minimum criterion (monitoring results directly comparable to criterion).
(8) Nutrient criteria – Lewis and Clark Lake has been assigned the following nutrient criteria by Nebraska for 2010 Section 303(d) and 305(b) assessment: Chlorophyll a = 10 ug/l, Total Nitrogen = 1 mg/l, and Total Phosphorus = 50 ug/l.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

* The highlighted mean value indicates use impairment based on State of Nebraska 2010 Section 303(d) impairment assessment criteria.

Plate 352. Summary of monthly (May through September) water quality conditions monitored in Lewis and Clark Lake near the Bloomfield Recreation Area (Site GPTLK0819DW) during the 3-year period 2008 through 2010.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	13	1206.5	1206.4	1205.5	1207.5	-----	-----	-----
Water Temperature (°C)	0.1	101	21.1	22.1	10.2	26.9	27[1,2,6], 29[1,2,6]	0	0%
Dissolved Oxygen (mg/l)	0.1	101	8.8	8.6	5.1	13.3	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	101	102.4	101.6	58.9	156.2	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	98	8.9	8.6	6.4	13.3	5[1,7]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	3	6.0	5.9	5.1	7.0	5[1,7]	0	0%
Specific Conductance (umhos/cm)	1	101	714	711	636	775	2,000[4]	0	0%
pH (S.U.)	0.1	101	8.4	8.4	7.8	8.8	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Turbidity (NTUs)	1	94	25	22	2	123	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	101	326	339	190	456	-----	-----	-----
Secchi Depth (in.)	1	13	22	18	16	40	-----	-----	-----
Alkalinity, Total (mg/l)	7	26	152	153	134	164	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	26	5.4	3.3	2.4	39.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	26	14	13	6	29	-----	-----	-----
Chloride (mg/l)	1	18	12	12	8	14	438[3,6], 250[3,8]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	78	28*	23	7	138	10[10]	67	86%
Chlorophyll *a* (ug/l) – Lab Determined	1	13	25*	18	8	76	10[10]	12	92%
Color (S.U. - APHA)	1	17	8	8	4	15	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	26	466	457	380	568	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	26	-----	0.02	n.d.	0.18	3.9 [1,6,9], 0.75[1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	26	0.6	0.6	0.2	1.5	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	26	-----	0.05	n.d.	0.50	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/l)	0.1	26	0.8	0.7	0.2	1.8	1[10]	6	28%
Phosphorus, Dissolved (mg/l)	0.02	25	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	26	0.06*	0.06	0.02	0.15	0.05[10]	15	58%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	26	-----	n.d.	n.d.	0.07	-----	-----	-----
Sulfate (mg/l)	1	26	204	203	172	233	875[3,6], 500[3,8]	0	0%
Suspended Solids, Total (mg/l)	4	26	15	17	n.d.	39	158[1,6], 90[1,8]	0	0%
Microcystin, Total (ug/l)	0.2	13	-----	n.d.	n.d.	0.2	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Nutrient criteria – Lewis and Clark Lake has been assigned the following nutrient criteria by Nebraska for 2010 Section 303(d) and 305(b) assessment: Chlorophyll a = 10 ug/l, Total Nitrogen = 1 mg/l, and Total Phosphorus = 50 ug/l.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

* The highlighted mean values indicate use impairment based on State of Nebraska 2010 Section 303(d) impairment assessment criteria.

Plate 353. Summary of monthly (June through September) water quality conditions monitored in Lewis and Clark Lake near the Devils Nest Area (site GPTLK0822DW) during the 3-year period 2008 through 2010.

Parameter	Monitoring Results(A)						Water Quality Standards Attainment		
	Detection Limit(B)	No. of Obs.	Mean(C)	Median	Min.	Max.	State WQS Criteria(D)	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	14	1206.5	1206.5	1205.5	1207.5	-----	-----	-----
Water Temperature (°C)	0.1	80	20.9	21.9	10.0	26.4	27(1,2,6), 29(1,2,6)	0	0%
Dissolved Oxygen (mg/l)	0.1	80	8.8	8.6	5.7	13.6	5(1,7)	0	0%
Dissolved Oxygen (% Sat.)	0.1	80	101.3	100.3	69.8	138.2	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)(E)	0.1	80	101.3	100.3	69.8	138.2	5(1,7)	0	0%
Hypolimnion Dissolved Oxygen (mg/l)(E)	0.1	0	-----	-----	-----	-----	5(1,7)	-----	-----
Specific Conductance (umhos/cm)	1	80	718	720	647	769	-----	-----	-----
pH (S.U.)	0.1	80	8.3	8.3	7.9	8.7	6.5(1,3,7), 9.0(1,3,6), 9.5(5,6)	0	0%
Turbidity (NTUs)	1	72	25	20	5	83	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	80	329	340	183	445	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	62	29*	26	4	81	10(8)	50	81%
Secchi Depth (in)	1	14	20	18	12	33	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) Nutrient criteria – Lewis and Clark Lake has been assigned the following nutrient criteria by Nebraska for 2010 Section 303(d) and 305(b) assessment: Chlorophyll a = 10 ug/l, Total Nitrogen = 1 mg/l, and Total Phosphorus = 50 ug/l.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

* The highlighted mean value indicates use impairment based on State of Nebraska 2010 Section 303(d) impairment assessment criteria.

Plate 354. Summary of monthly (May through September) water quality conditions monitored in Lewis and Clark Lake near the Charley Creek Area (Site GPTLK0825DW) during the 3-year period 2008 through 2010.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	14	1206.5	1206.5	1205.5	1207.5	-----	-----	-----
Water Temperature (°C)	0.1	55	20.7	21.7	14.0	26.1	27[1,2,6], 29[1,2,6]	0	0%
Dissolved Oxygen (mg/l)	0.1	55	8.6	8.2	6.2	12.2	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	55	99.3	95.2	79.4	128.1	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	55	8.6	8.2	6.2	12.2	5[1,7]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0	-----	-----	-----	-----	5[1,7]	-----	-----
Specific Conductance (umhos/cm)	1	55	691	686	609	738	2,000[4]	0	0%
pH (S.U.)	0.1	55	8.3	8.3	8.0	8.5	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Turbidity (NTUs)	1	50	38	37	11	91	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	55	332	356	203	436	-----	-----	-----
Secchi Depth (in.)	1	14	15	14	9	24	-----	-----	-----
Alkalinity, Total (mg/l)	7	13	153	154	135	172	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	13	4.2	3.9	1.8	8.3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	13	13	13	8	23	-----	-----	-----
Chloride (mg/l)	1	9	12	11	11	14	438[3,6], 250[3,8]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	46	26*	22	8	50	8[10]	34	100%
Chlorophyll *a* (ug/l) – Lab Determined	1	13	22*	15	8	46	8[10]	9	100%
Color (S.U. - APHA)	1	8	9	9	n.d.	16	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	13	447	446	380	542	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	13	-----	n.d.	n.d.	0.09	3.9 [1,6,9], 0.77[1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	13	0.7	0.6	0.2	1.4	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	13	-----	0.15	n.d.	0.42	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/l)	0.1	13	0.8	0.7	0.4	1.5	1[10]	3	23%
Phosphorus, Dissolved (mg/l)	0.02	12	-----	0.02	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	13	0.07*	0.08	n.d.	0.16	0.05[10]	9	69%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	13	-----	n.d.	n.d.	0.05	-----	-----	-----
Sulfate (mg/l)	1	13	192	189	175	217	875[3,6], 500[3,8]	0	0%
Suspended Solids, Total (mg/l)	4	13	27	27	6	52	158[1,6], 90[1,8]	0	0%
THM Formation Potential, Total	4	9	224	156	74	561	-----	-----	-----
Microcystin, Total (ug/l)	0.2	13	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Nutrient criteria – Lewis and Clark Lake has been assigned the following nutrient criteria by Nebraska for 2010 Section 303(d) and 305(b) assessment: Chlorophyll a = 10 ug/l, Total Nitrogen = 1 mg/l, and Total Phosphorus = 50 ug/l.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5°C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1°C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5°C occurs over a 1-meter depth increment.

(F) Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

* The highlighted mean values indicate use impairment based on State of Nebraska 2010 Section 303(d) impairment assessment criteria.

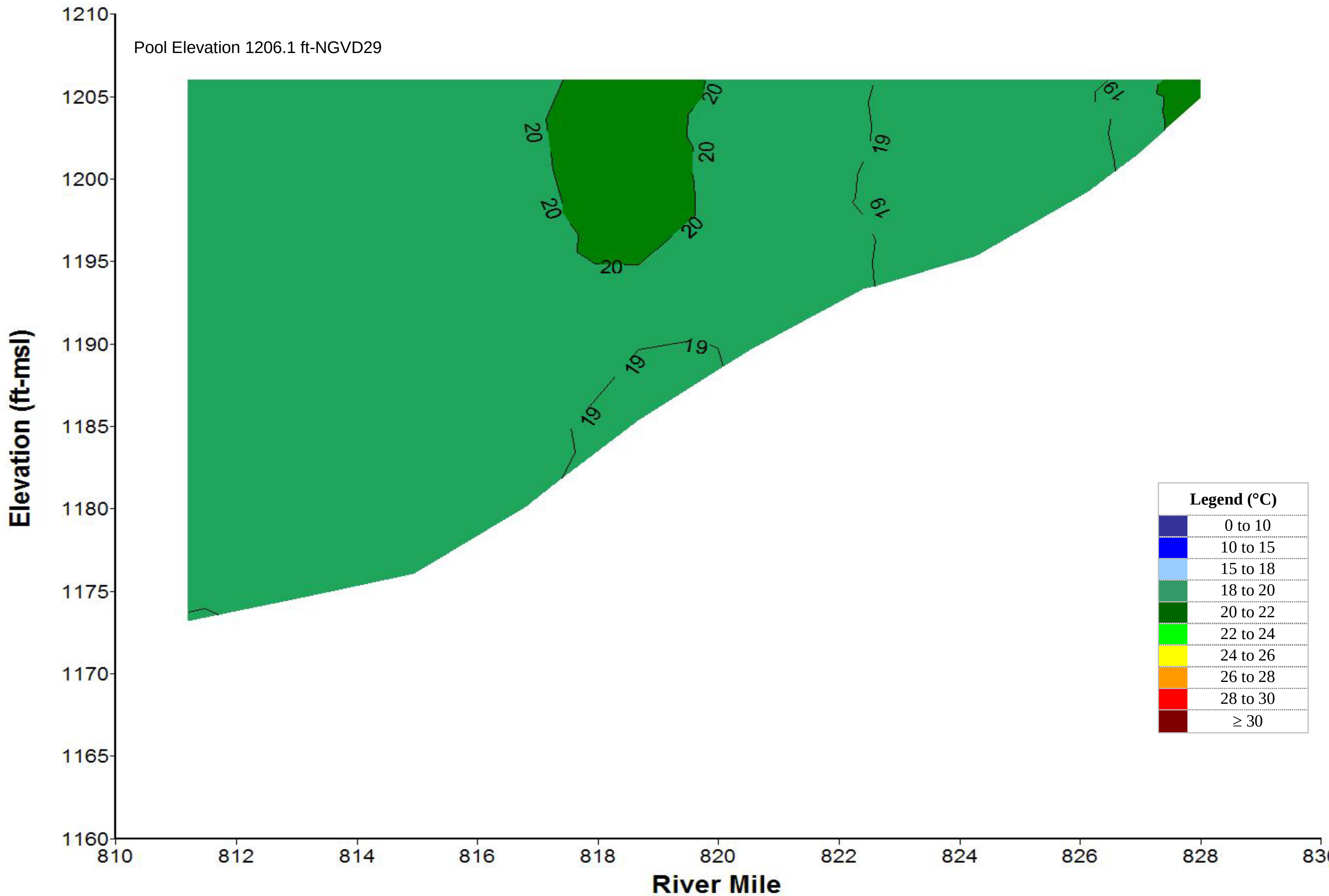

Plate 355. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on June 8, 2010.

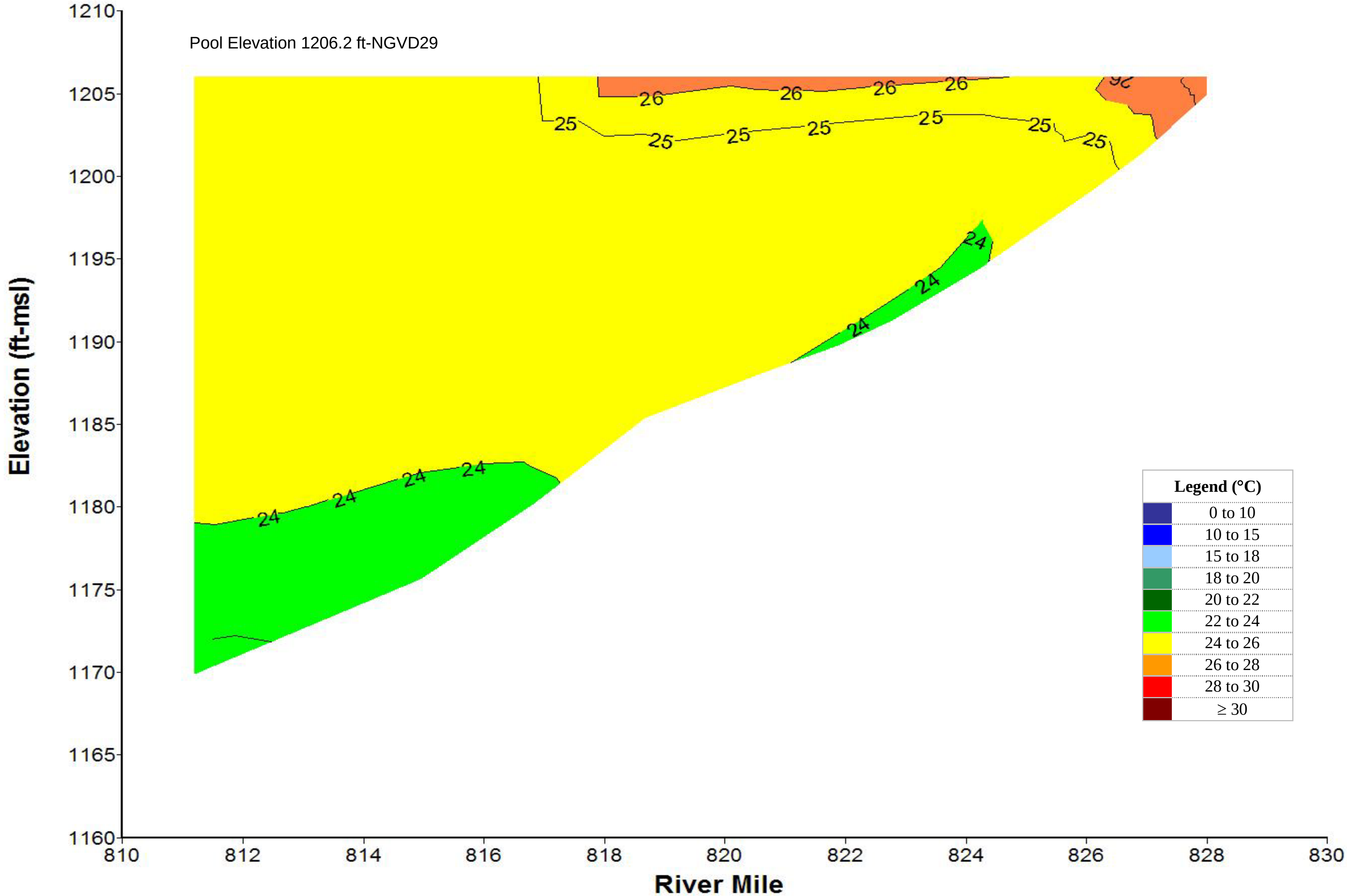

Plate 356. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on July 16, 2010.

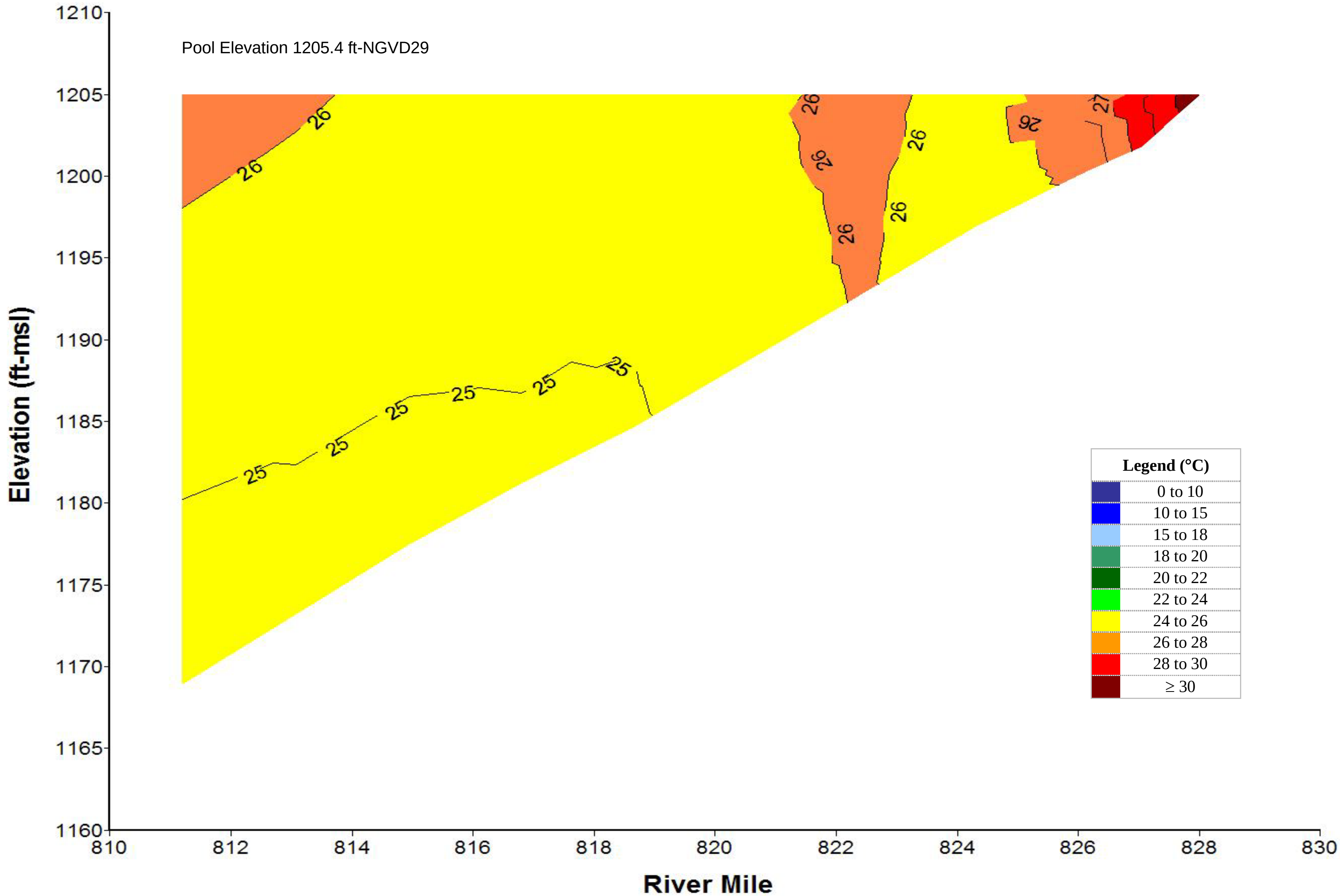

Plate 357. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on August 19, 2010.

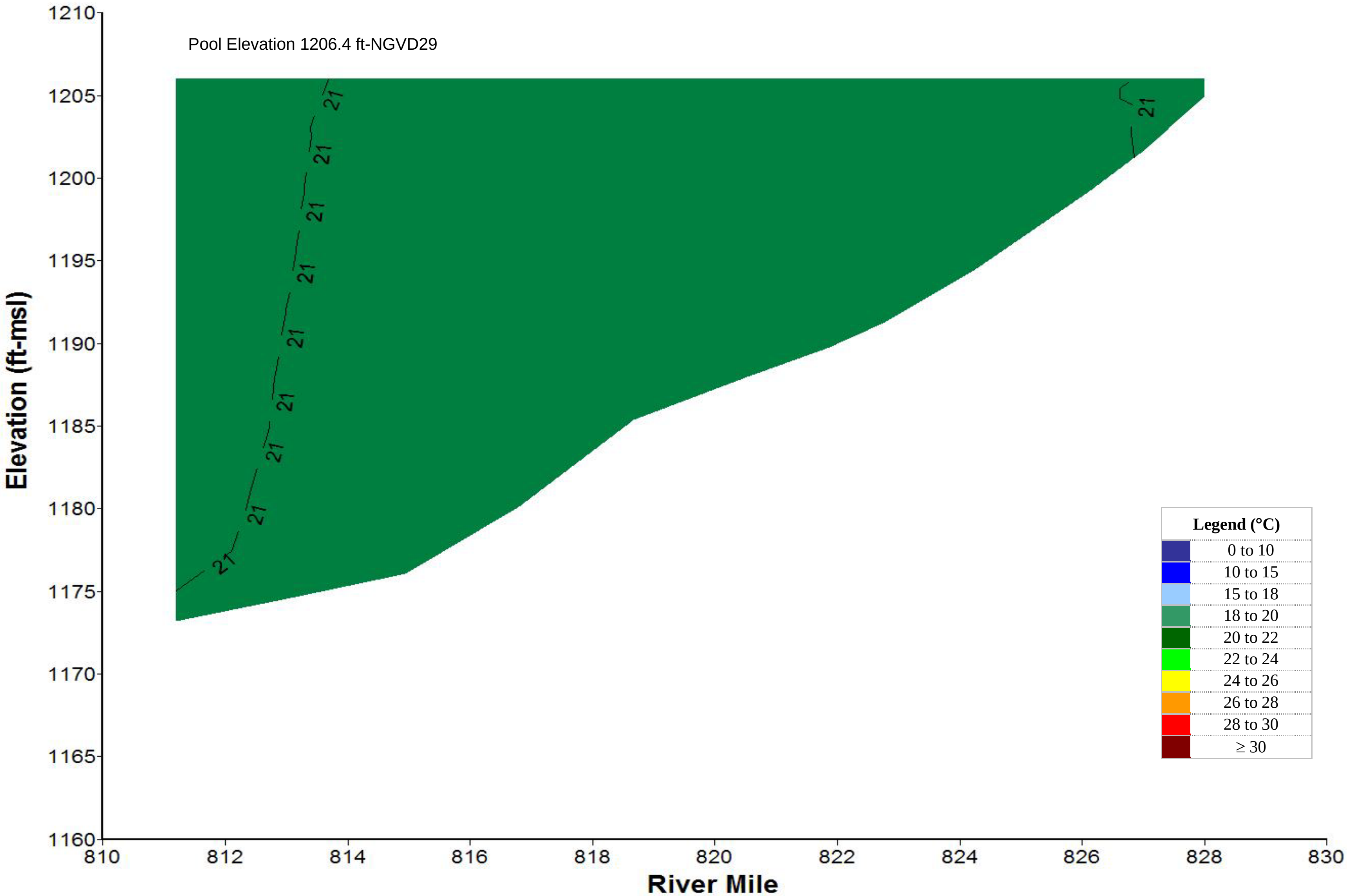

Plate 358. Longitudinal water temperature (°C) contour plot of Lewis and Clark Lake based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on September 17, 2010**.**

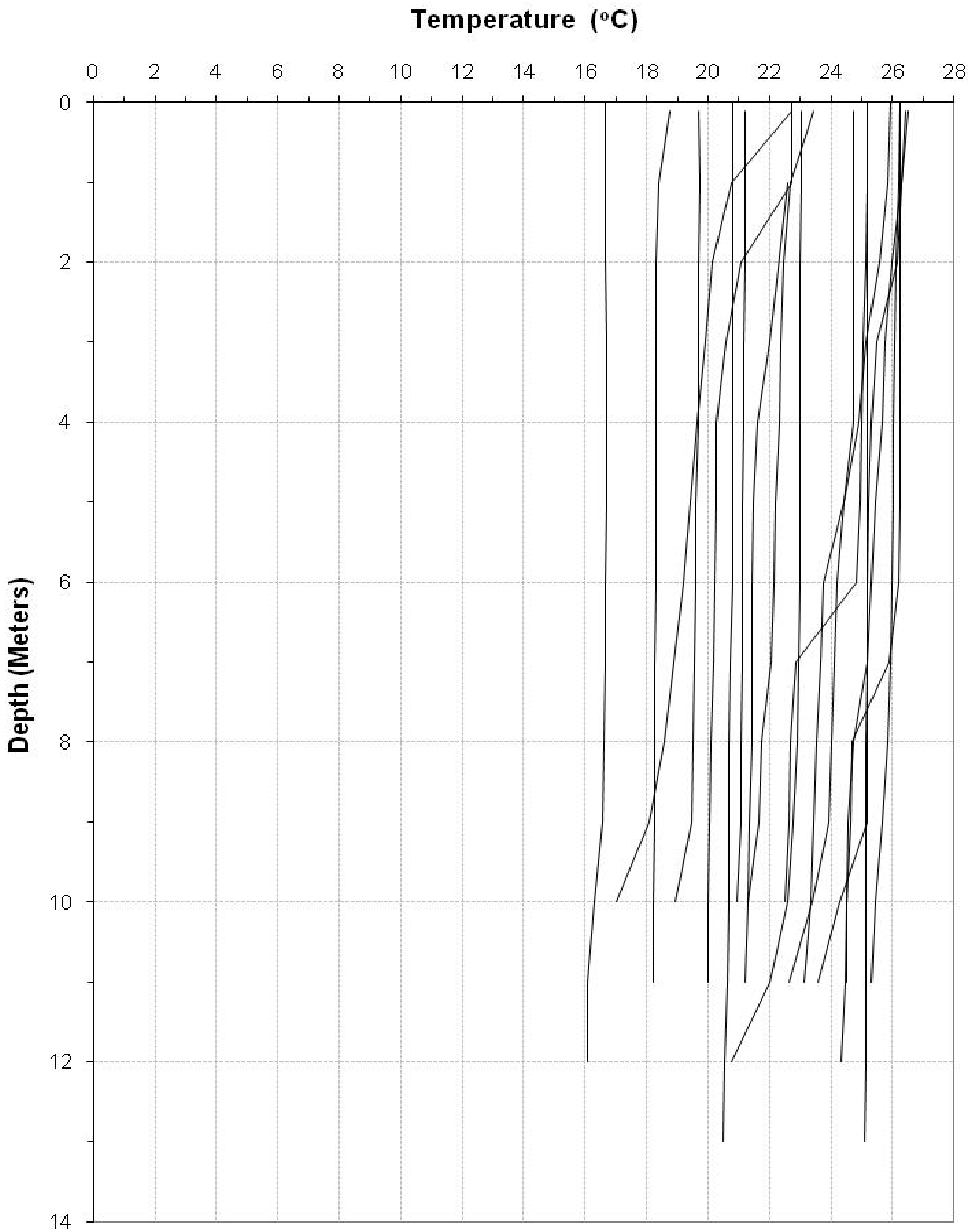

Plate 359. Temperature depth profiles for Lewis and Clark Lake generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., site GPTLK0811A) during the summer months over the 5-year period 2006 to 2010.

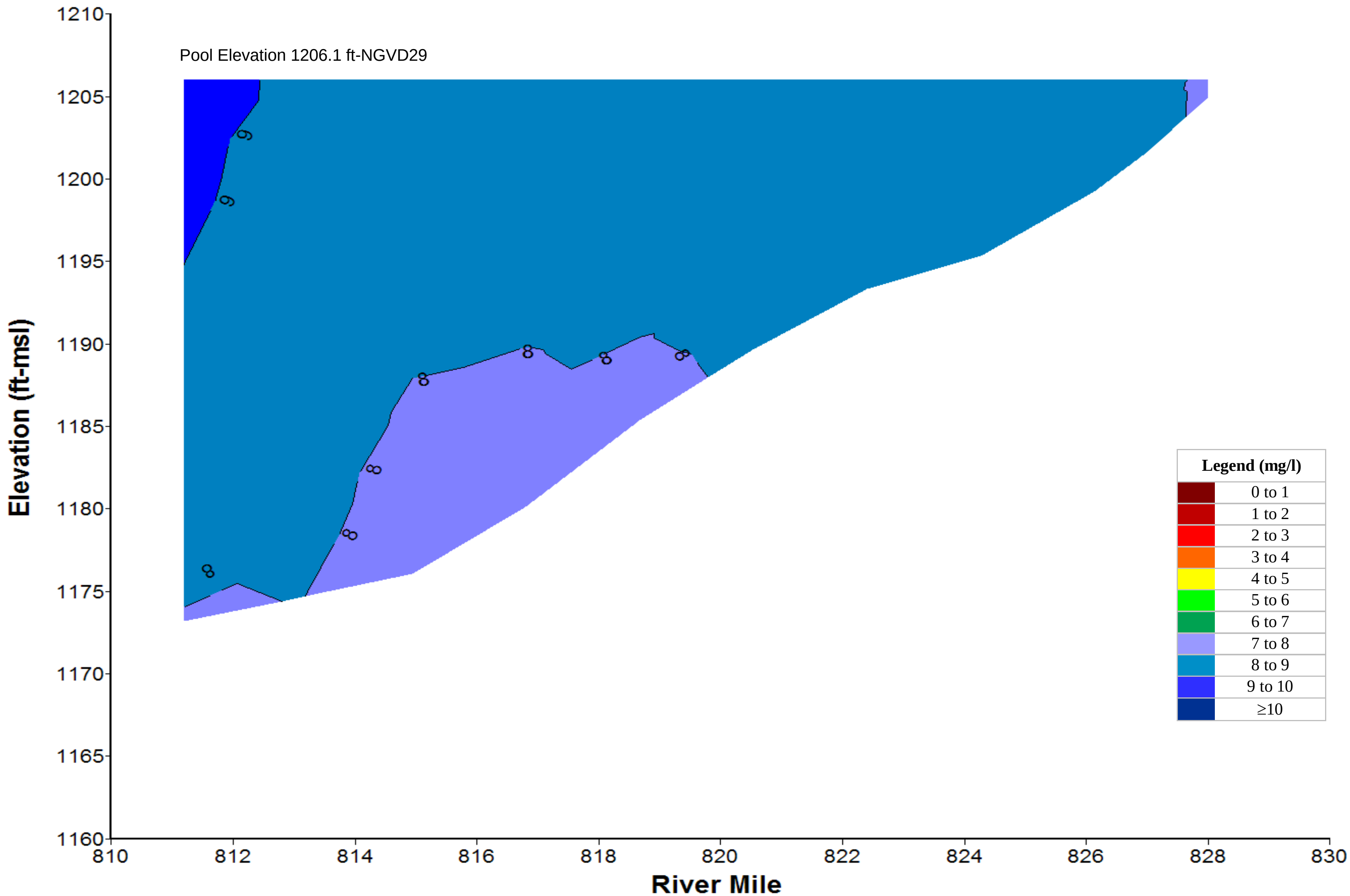

Plate 360. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on June 10, 2010.

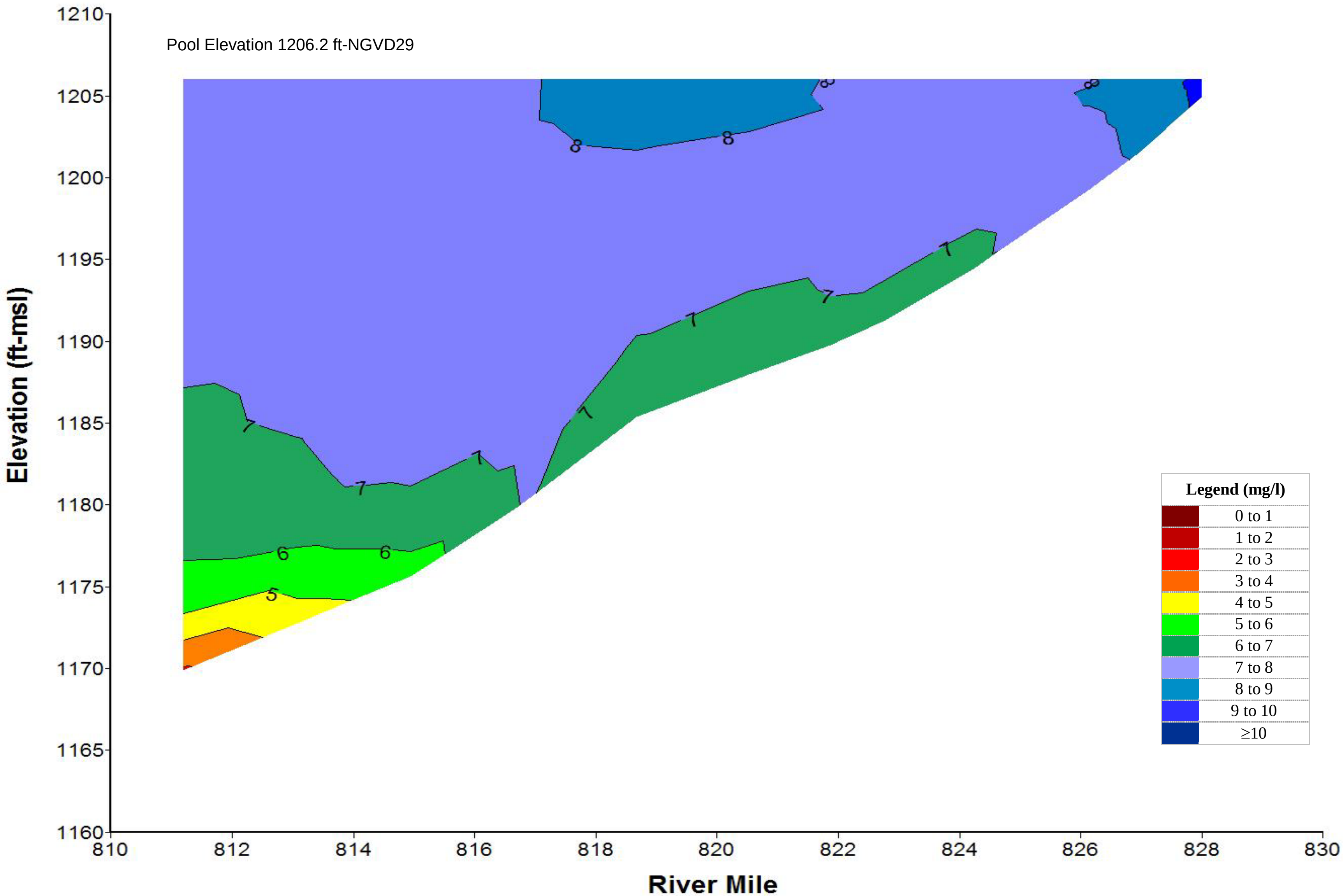

Plate 361. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on July 16, 2010.

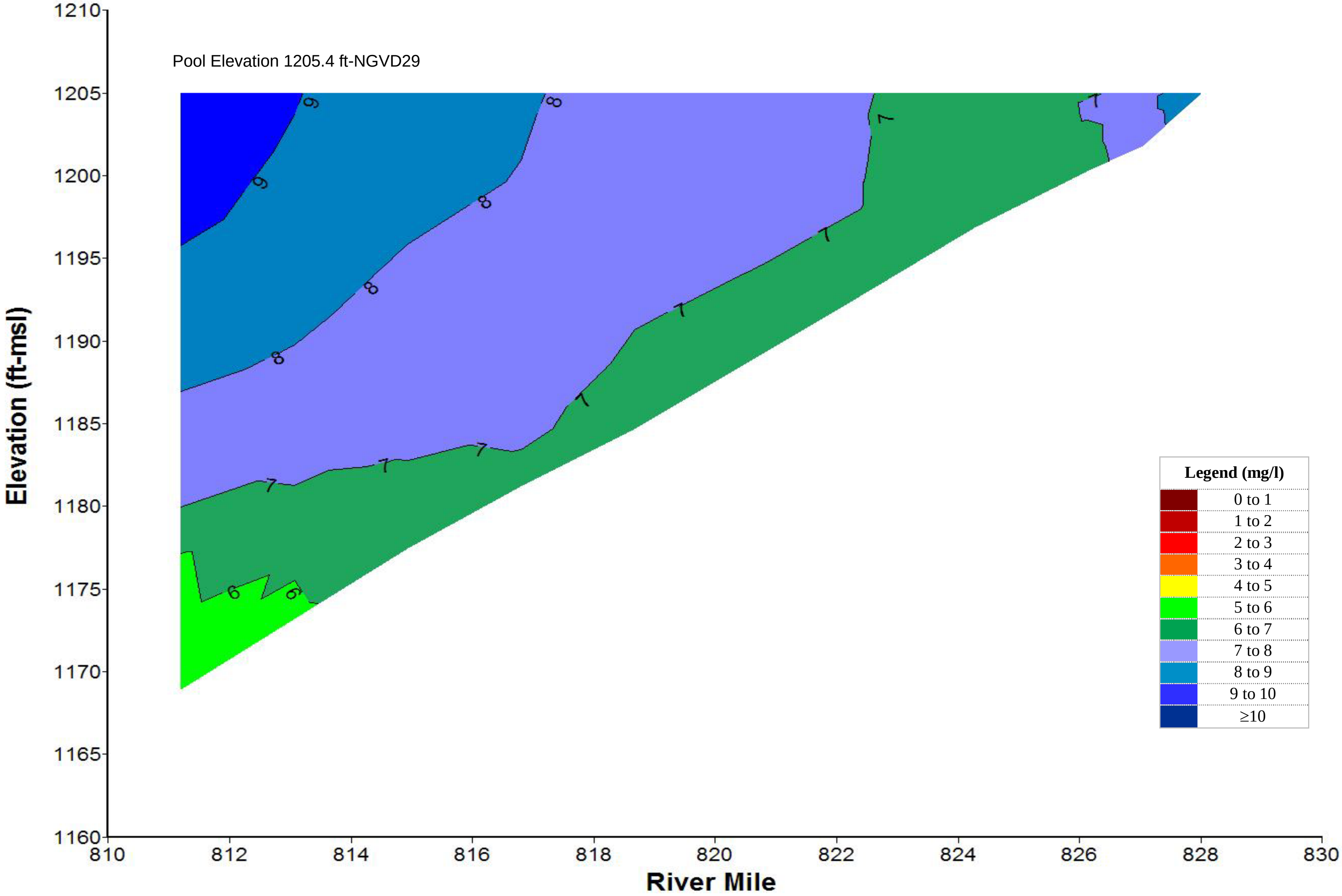

Plate 362. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on August 19, 2010.

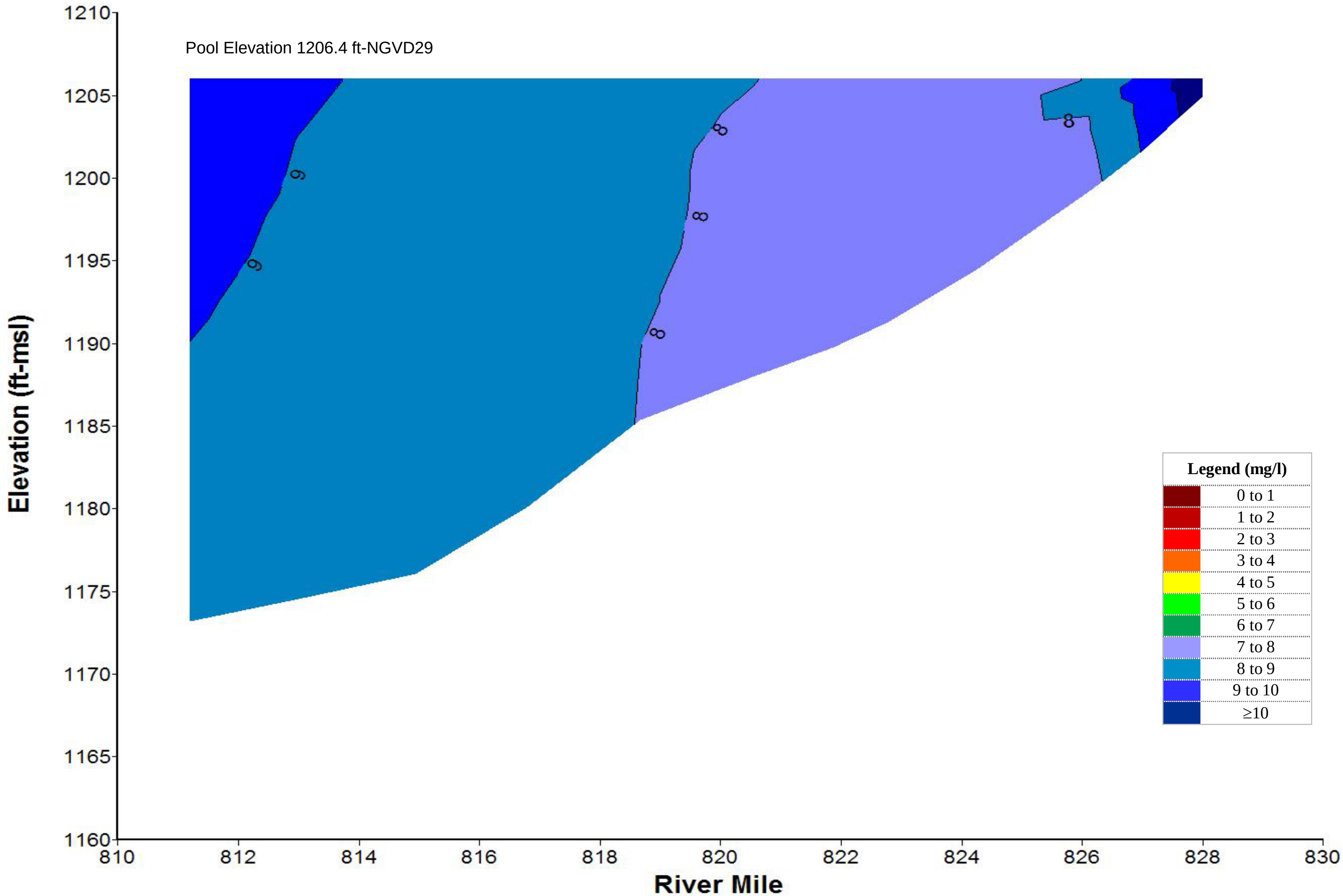

Plate 363. Longitudinal dissolved oxygen (mg/l) contour plot of Lewis and Clark Lake based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on September 17, 2010**.**

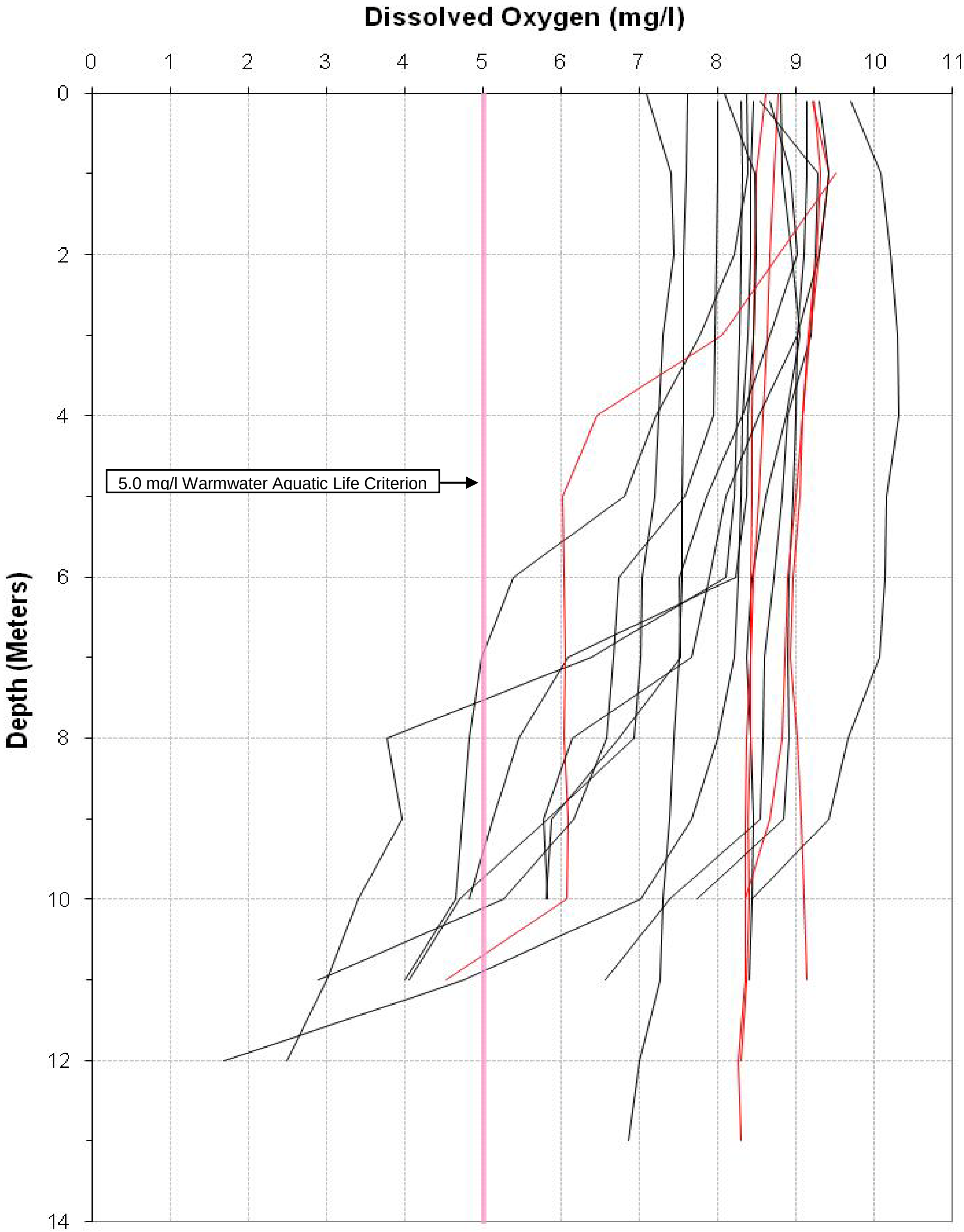

Plate 364. Dissolved oxygen depth profiles for Lewis and Clark Lake generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., site GPTLK0811A) during the summer months over the 5-year period 2006 to 2010.
(Note: Red profile plots were measured in the month of September.)

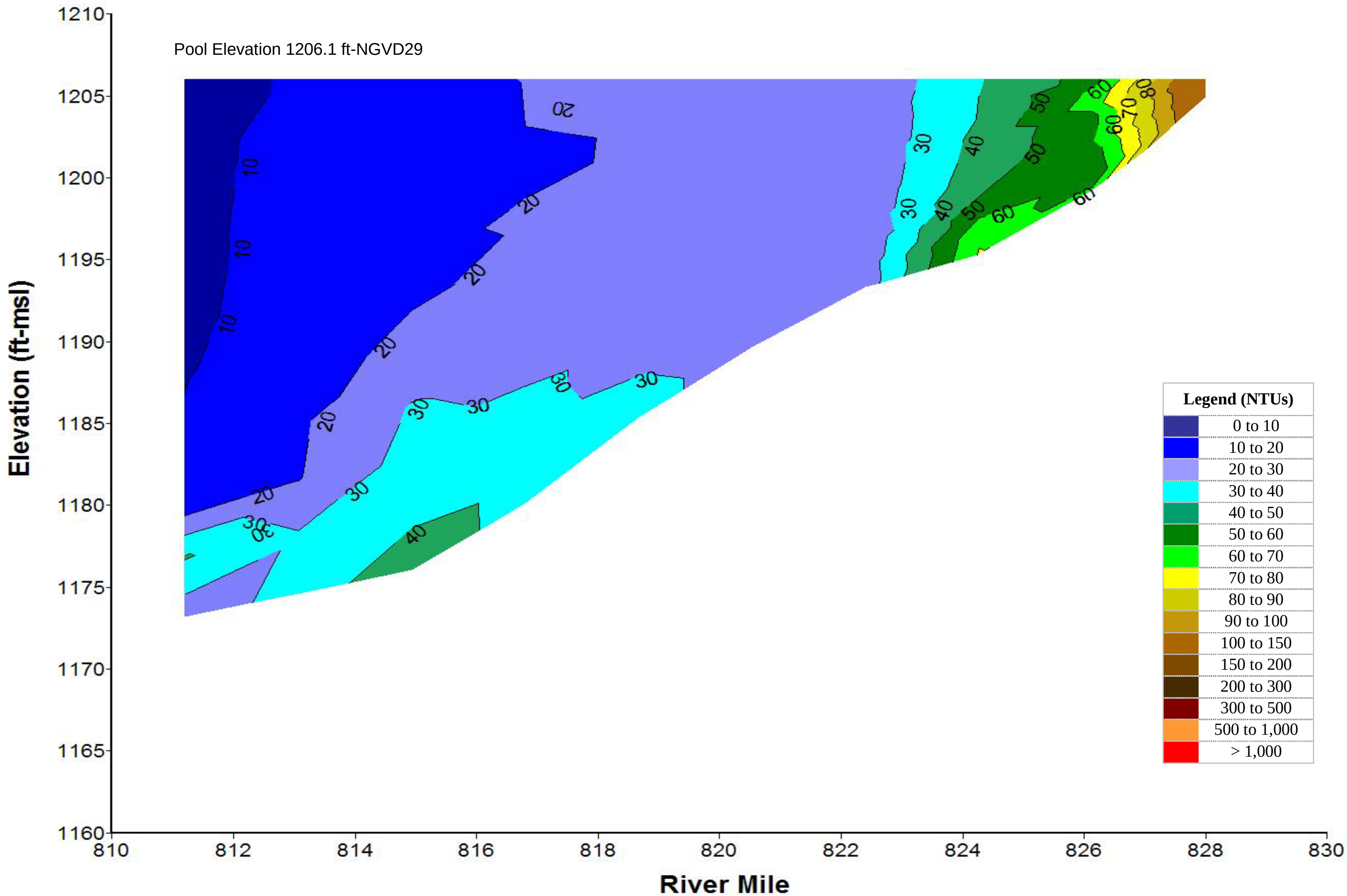

Plate 365. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on June 8, 2010.

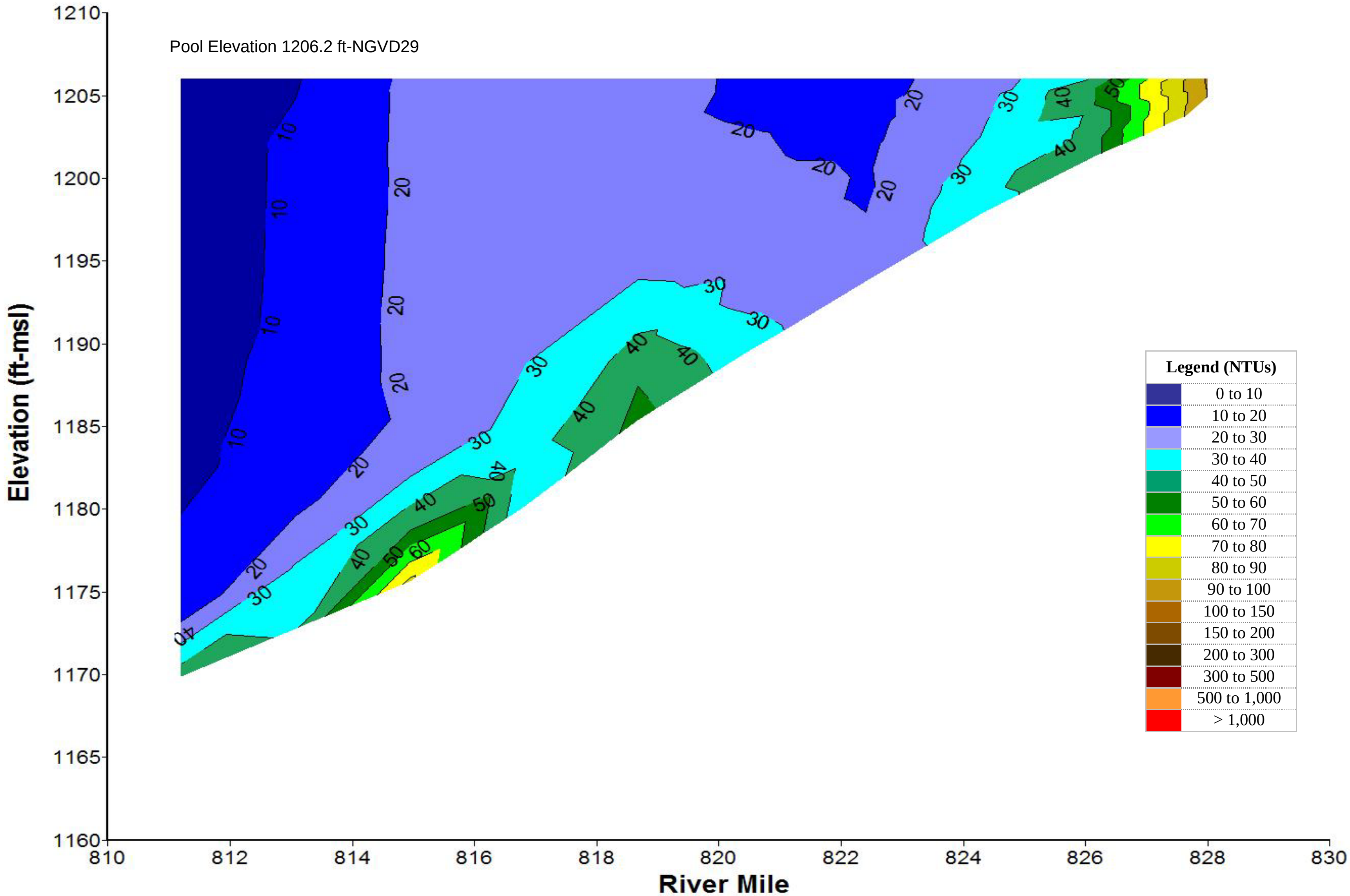

Plate 366. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on July 16, 2010.

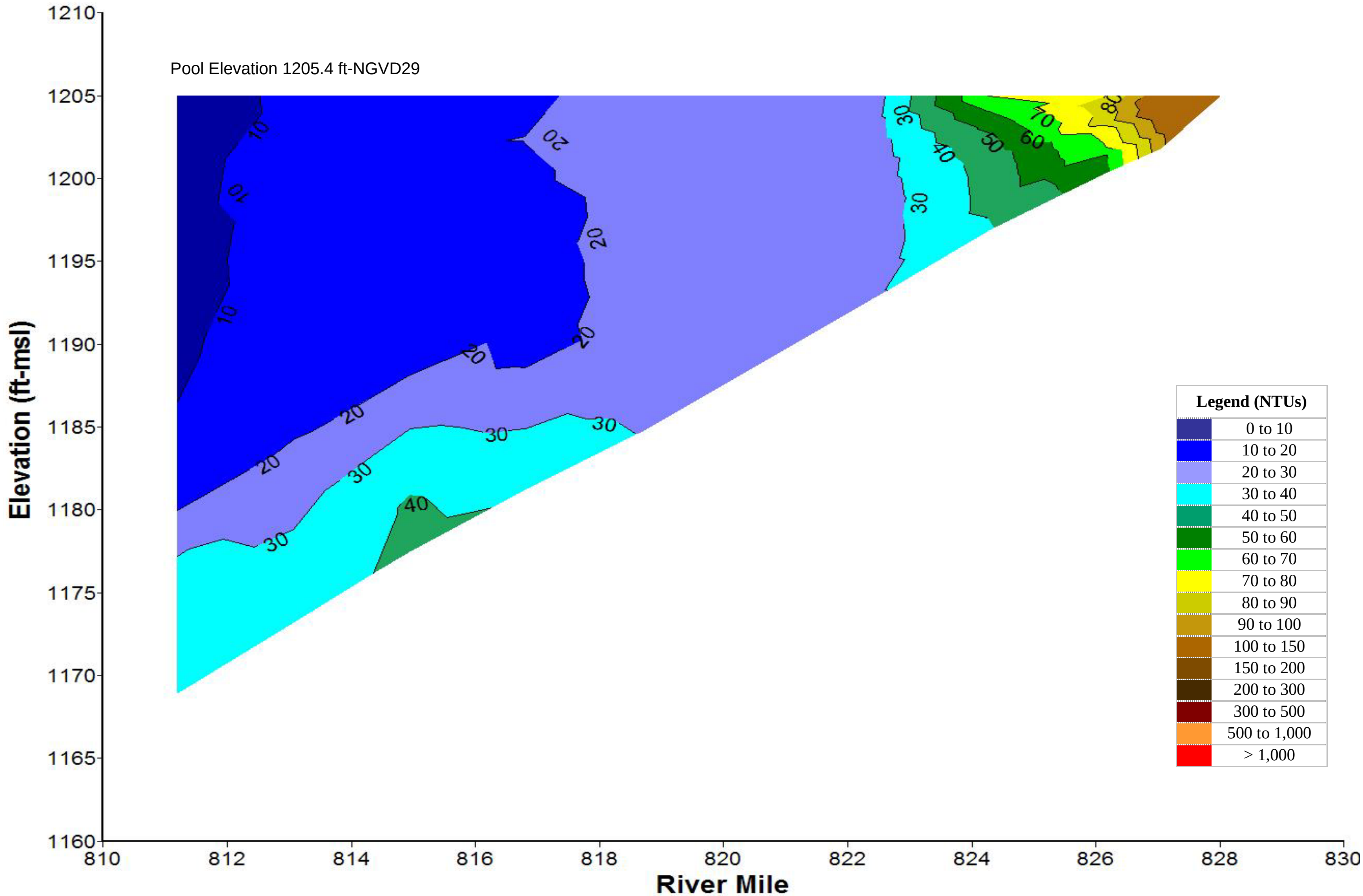

Plate 367. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on August 19, 2010.

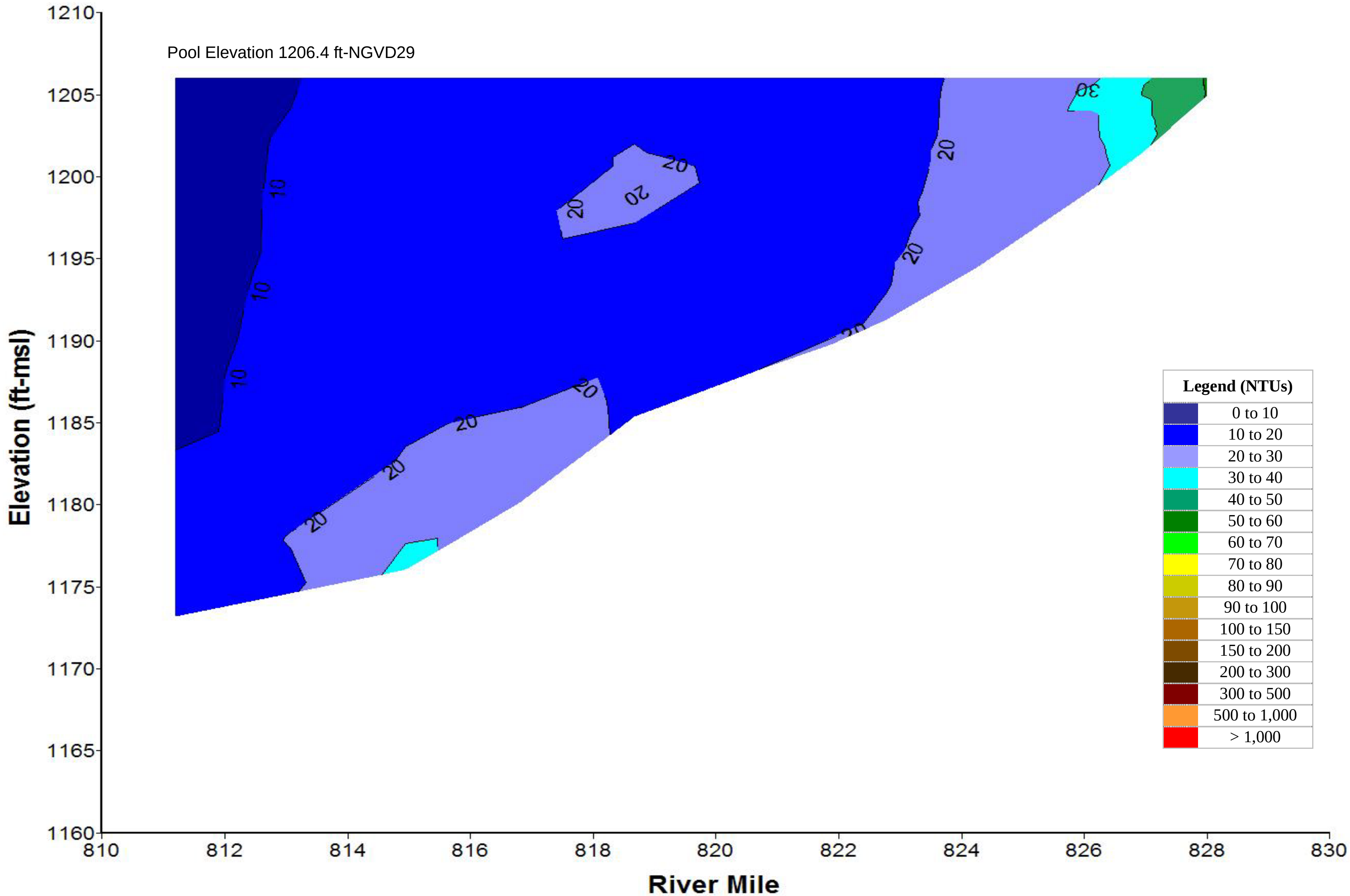

Plate 368. Longitudinal turbidity (NTUs) contour plot of Lewis and Clark Lake based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on September 17, 2010**.**

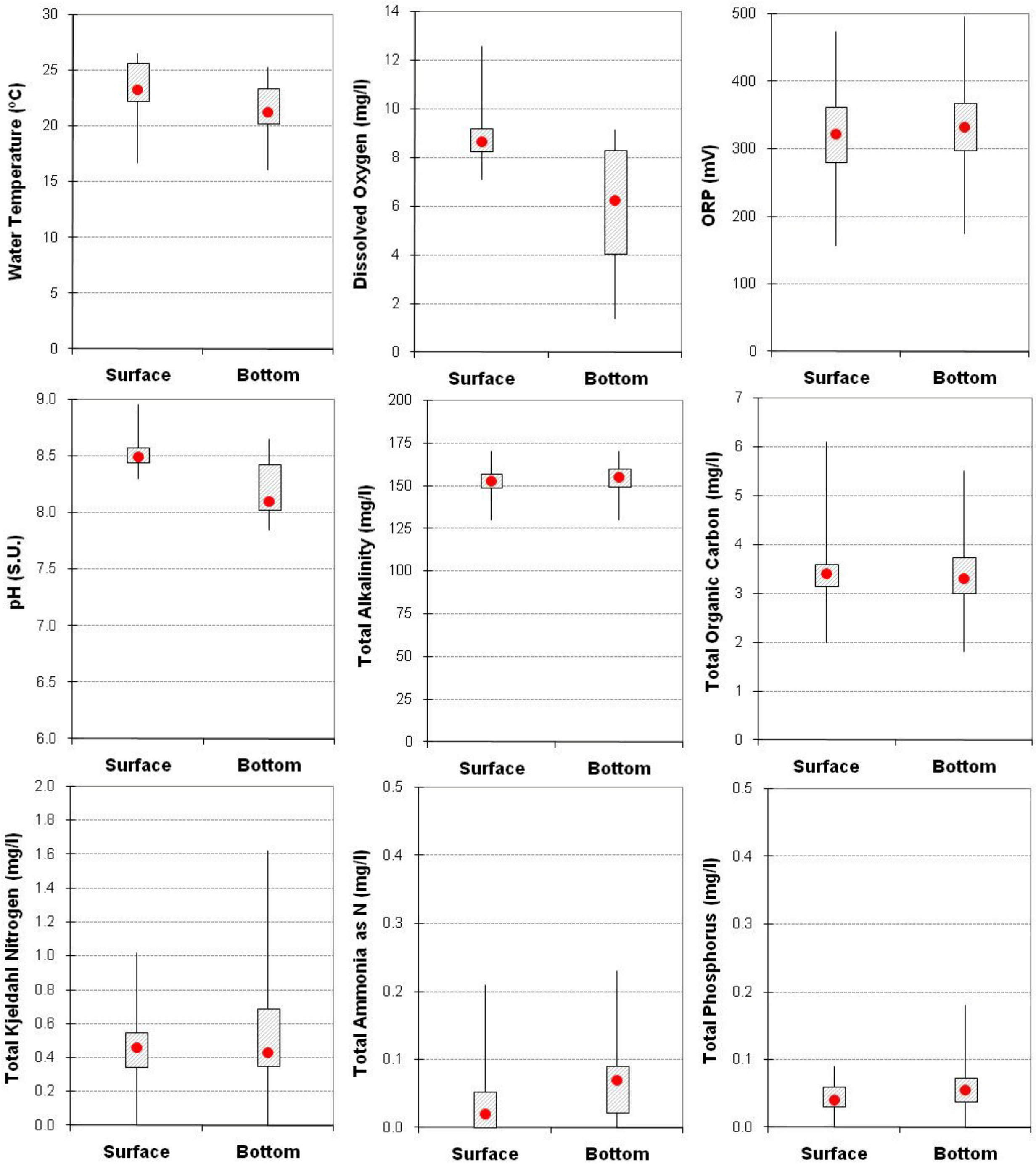

Plate 369. Box plots comparing paired surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus measurements taken in Lewis and Clark Lake at site GPTLK0811A during the summer months of the 5-year period 2006 through 2010.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 370. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected at the near-dam area of Lewis and Clark Lake (i.e., site GPTLK0811A) during the 5-year period 2006 through 2010.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
May 2006	1.1705	12	0.97	13	0.01	0	-----	1	<0.01	2	<0.01	0	-----	2	0.01
Jun 2006	0.2801	10	0.78	17	0.16	2	0.01	1	0.01	0	-----	1	0.03	1	0.01
Jul 2006	0.7108	15	0.89	9	0.06	1	<0.01	1	<0.01	1	<0.01	3	0.04	1	0.01
Aug 2006	0.5284	13	0.75	11	0.10	1	<0.01	1	<0.01	8	0.11	1	0.01	2	0.02
Sep 2006	0.5206	19	0.72	22	0.22	0	-----	1	0.01	4	0.03	0	-----	2	0.02
May 2007	3.5396	10	0.90	10	0.09	0	-----	1	<0.01	0	-----	0	-----	0	-----
Jun 2007	1.2427	11	0.83	4	0.11	2	0.03	2	0.02	1	<0.01	1	<0.01	0	-----
Jul 2007	0.8768	8	0.92	9	0.05	1	<0.01	1	0.03	0	-----	1	<0.01	0	-----
Aug 2007	0.6745	8	0.69	11	0.06	0	-----	2	0.02	4	0.03	2	0.18	1	0.01
Sep 2007	2.4928	12	0.88	13	0.02	0	-----	1	0.01	5	0.10	1	<0.01	2	<0.01
May 2008	1.9957	13	1.00	3	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	1	<0.01
Jun 2008	0.0013	9	0.70	10	0.17	1	<0.01	1	0.13	1	<0.01	1	<0.01	0	-----
Jul 2008	0.0019	23	0.98	12	0.01	3	<0.01	1	<0.01	6	<0.01	1	<0.01	1	<0.01
Aug 2008	0.7722	6	0.88	11	0.01	2	<0.01	1	0.08	4	0.02	1	<0.01	2	0.01
Sep 2008	0.6705	10	0.92	19	0.02	0	<0.01	2	0.05	4	<0.01	2	<0.01	1	<0.01
May 2009	23.7660	19	0.93	8	0.02	2	<0.01	2	0.05	1	<0.01	1	<0.01	1	<0.01
Jun 2009	0.0021	9	0.99	11	0.01	0	-----	0	-----	1	<0.01	0	-----	1	<0.01
Jul 2009	2.2125	13	0.91	9	0.04	0	-----	1	0.05	0	-----	1	<0.01	1	<0.01
Aug 2009	1.0469	9	0.35	8	0.09	2	0.05	1	0.18	5	0.05	2	0.27	0	-----
Sep 2009	1.6888	10	0.24	7	0.09	1	0.04	1	0.52	7	0.08	2	0.03	2	<0.01
May 2010	3.3778	15	0.97	7	0.02	2	<0.01	1	0.01	0	-----	0	-----	0	-----
Jul 2010	0.2769	10	0.77	16	0.09	0	-----	2	0.12	3	0.02	0	-----	1	<0.01
Sep 2010	0.9476	6	0.95	17	0.01	0	-----	2	0.02	7	0.02	3	0.01	1	<0.01
Mean	**2.1216**	**11.7**	**0.82**	**11.2**	**0.06**	**0.9**	**0.01**	**1.2**	**0.06**	**2.8**	**0.03**	**1.0**	**0.04**	**1.0**	**0.01**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 371. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected from the middle reaches of Lewis and Clark Lake (i.e., site GPTLK0819DW) during the 3-year period 2008 through 2010.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
Jun 2008	0.0021	10	0.58	15	0.10	2	<0.01	1	0.30	2	0.02	1	<0.01	1	<0.01
Jul 2008	0.0009	10	0.86	15	0.06	1	<0.01	1	0.05	4	<0.01	1	0.01	2	0.01
Aug 2008	0.2888	7	0.77	10	0.06	1	<0.01	1	0.15	2	<0.01	1	0.01	1	0.01
Sep 2008	0.3856	11	0.92	14	0.05	0	-----	1	<0.01	3	0.01	3	0.02	1	<0.01
May 2009	8.8087	17	0.73	9	0.04	1	<0.01	2	0.23	0	-----	0	-----	0	-----
Jun 2009	2.0366	29	0.92	7	0.08	1	<0.01	1	<0.01	0	-----	0	-----	0	-----
Jul 2009	1.1121	15	0.68	10	0.15	0	-----	1	0.16	1	<0.01	1	<0.01	1	0.01
Aug 2009	0.3067	12	0.57	11	0.15	1	0.13	1	0.09	5	0.06	1	<0.01	0	-----
Sep 2009	2.2394	21	0.67	12	0.08	1	<0.01	2	0.20	3	0.04	0	-----	3	<0.01
Jul 2010	0.2207	6	0.22	10	0.19	1	<0.01	1	0.44	2	0.02	1	0.03	1	0.09
Sep 2010	1.0848	15	0.98	14	<0.01	0	-----	2	0.01	3	0.01	0	-----	1	<0.01
Mean	**1.4988**	**13.9**	**0.72**	**11.5**	**0.09**	**0.8**	**0.02**	**1.3**	**0.15**	**2.3**	**0.02**	**0.8**	**0.01**	**1.0**	**0.02**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 372. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected from the upper reaches of Lewis and Clark Lake (i.e., site GPTLK0825DW) during the 3-year period 2008 through 2010.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta	
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.
Jun 2008	0.0008	19	0.68	16	0.12	3	0.02	1	0.16	2	<0.01	1	<0.01	1	<0.01
Jul 2008	0.0004	17	0.62	12	0.15	1	<0.01	1	0.23	4	<0.01	0	-----	0	-----
Aug 2008	0.1136	13	0.67	5	0.07	0	-----	1	0.24	1	<0.01	0	-----	1	0.02
Sep 2008	0.5900	10	0.70	16	0.13	0	-----	2	0.14	4	<0.01	2	0.03	1	<0.01
May 2009	2.2203	30	0.88	9	0.04	1	<0.01	2	0.08	0	-----	0	-----	0	-----
Jun 2009	4.0218	31	0.62	7	0.38	0	-----	0	-----	0	-----	1	<0.01	0	-----
Jul 2009	1.7597	27	0.91	6	0.02	0	-----	2	0.06	0	-----	2	0.01	2	<0.01
Aug 2009	1.2769	19	0.67	14	0.20	0	-----	1	0.11	3	<0.01	1	0.02	1	<0.01
Sep 2009	1.0819	25	0.60	11	0.12	0	-----	1	0.20	5	0.06	0	-----	1	0.02
Jul 2010	0.1957	11	0.60	23	0.37	0	-----	1	0.01	1	<0.01	1	0.02	1	<0.01
Sep 2010	0.6673	20	0.97	13	0.02	0	-----	0	-----	1	0.01	1	<0.01	1	<0.01
Mean	**1.0844**	**21.2**	**0.71**	**10.7**	**0.14**	**0.6**	**0.01**	**1.2**	**0.15**	**2.1**	**0.01**	**0.8**	**0.01**	**0.8**	**0.01**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 373. Estimated biomass, number of species, and percent composition (based on biomass) by taxonomic grouping for zooplankton tow samples collected in Lewis and Clark Lake at Sites GPTLK0811A, GPTLK0819DW, and GPTLK0825DW during 2010.

Date	Estimated Biomass (µg/L dry wt.)	Cladocerans		Copepods		Rotifers		Ostracod	
		No. of Species	**Percent Comp.**	**No. of Species**	**Percent Comp.**	**No. of Species**	**Percent Comp.**	**No. of Species**	**Percent Comp.**
Site GPTLK08110A – Near Dam									
May 2010	32.281	2	0.19	3	0.47	9	0.34	-----	-----
July 2010	33.029	3	0.19	6	0.60	12	0.21	-----	-----
Sept 2010	10.012	2	0.27	4	0.66	8	0.07	-----	-----
Mean	**25.107**	**2.3**	**0.22**	**4.3**	**0.58**	**9.7**	**0.21**	-----	-----
Site GPTLK0819DW – Bloomfield Recreation Area									
May 2010	No Data								
July 2010	1.910	1	0.03	4	0.77	15	0.20	-----	-----
Sept 2010	1.951	7	0.37	7	0.58	9	0.03	1	0.02
Mean	**1.931**	**4.0**	**0.20**	**5.5**	**0.68**	**12.0**	**0.12**	-----	-----
Site GPTLK0825DW – Charley Creek									
May 2010	No Data								
July 2010	1.448	2	0.33	3	0.47	11	0.20	-----	-----
Sep 2010	4.091	5	0.27	6	0.72	6	0.01	1	<0.01
Mean	**2.770**	**3.5**	**0.30**	**4.5**	**0.60**	**8.5**	**0.11**	-----	-----

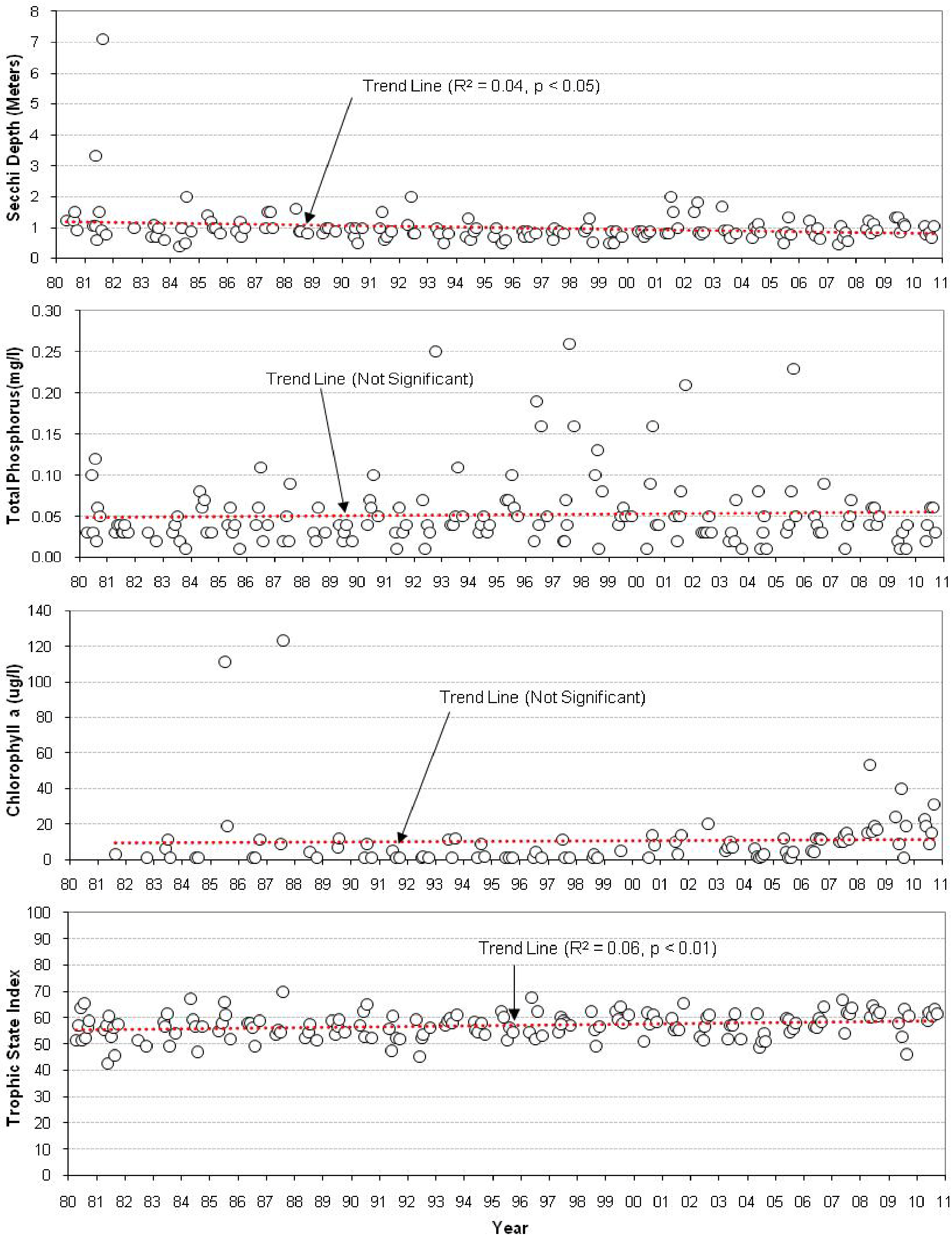

Plate 374. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Lewis and Clark Lake at the near-dam, ambient site (i.e., site GTPLK0811A) over the 31-year period of 1980 through 2010.

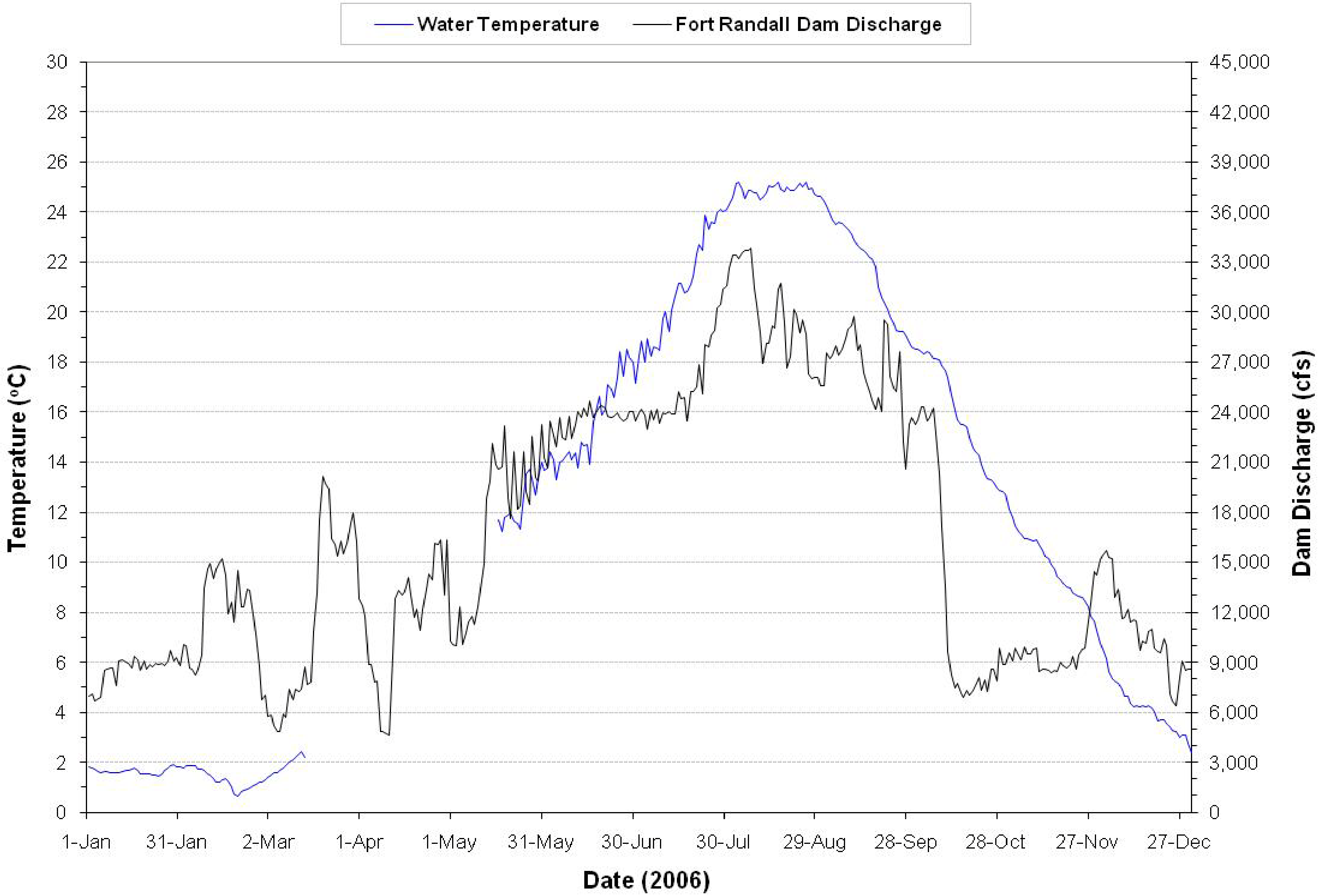

Plate 375. Mean daily water temperature and discharge of the Missouri River at Fort Randall Dam (i.e., site FTRPP1) for 2006. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Fort Randall Dam.
Note: Gaps in temperature plot are periods when monitoring equipment was not operational.

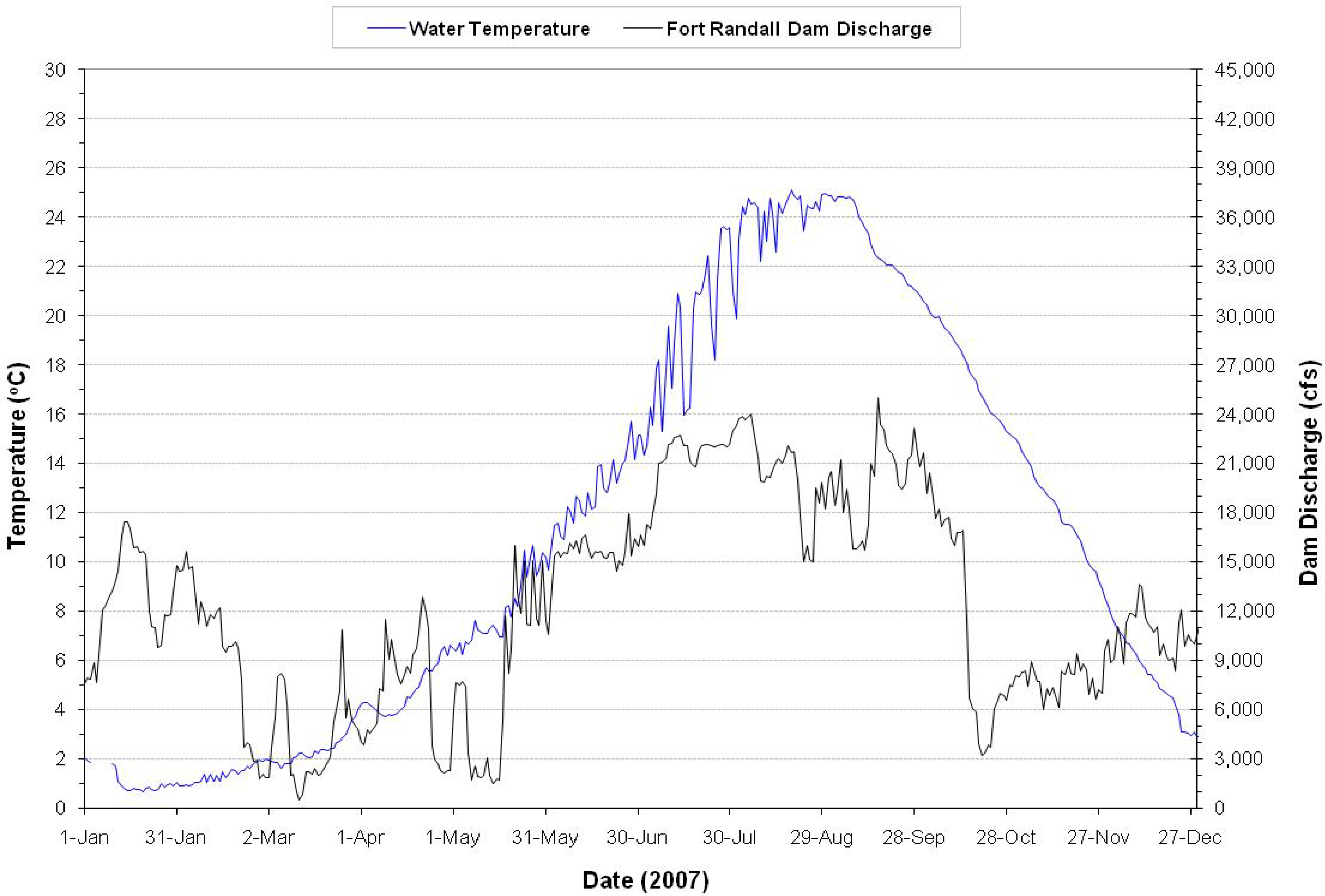

Plate 376. Mean daily water temperature and discharge of the Missouri River at Fort Randall Dam (i.e., site FTRPP1) for 2007. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Fort Randall Dam.

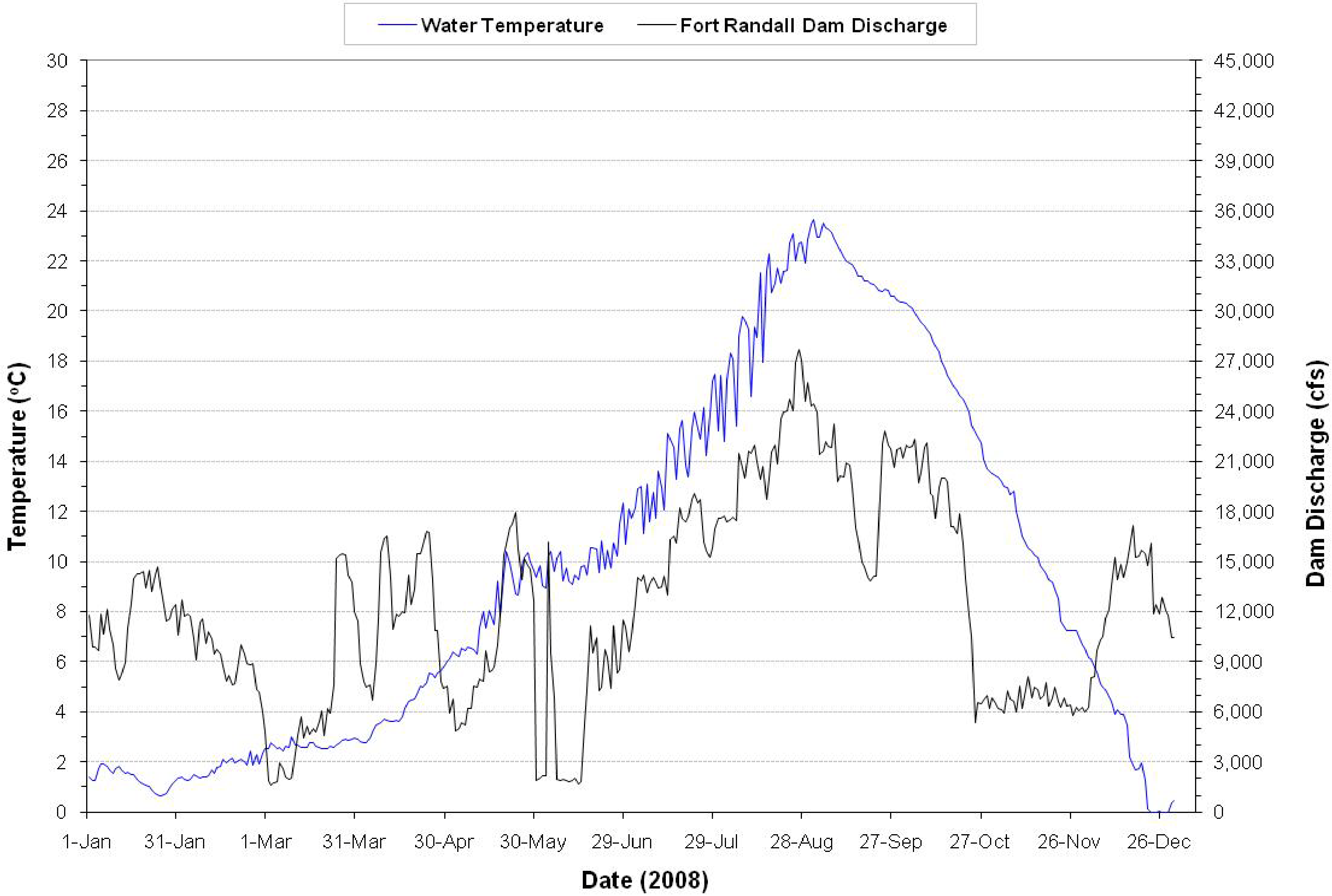

Plate 377. Mean daily water temperature and discharge of the Missouri River at Fort Randall Dam (i.e., site FTRPP1) for 2008. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Fort Randall Dam.

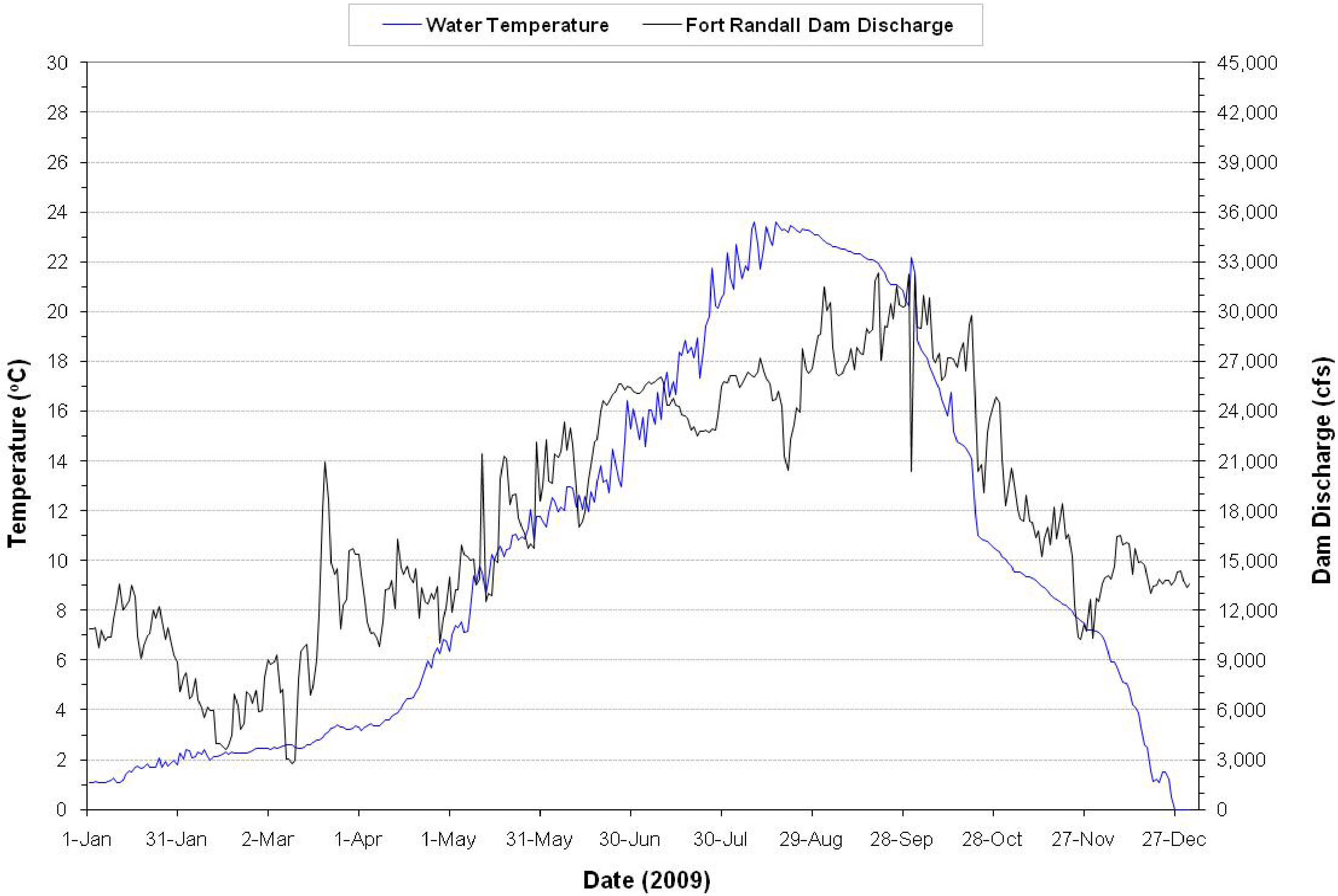

Plate 378. Mean daily water temperature and discharge of the Missouri River at Fort Randall Dam (i.e., site FTRPP1) for 2009. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Fort Randall Dam.

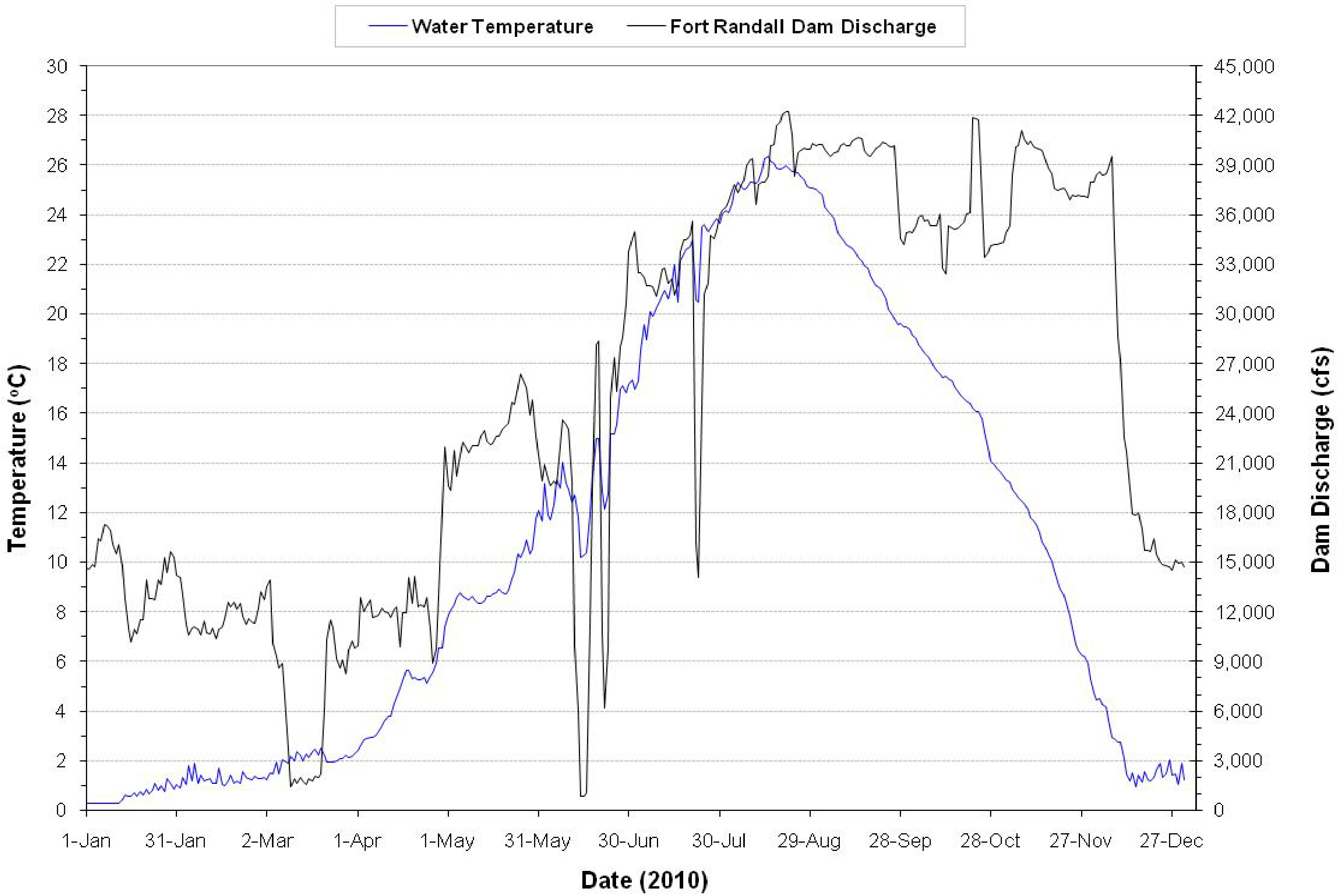

Plate 379. Mean daily water temperature and discharge of the Missouri River at Fort Randall Dam (i.e., site FTRPP1) for 2010. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Fort Randall Dam.

Plate 380. Summary of near-surface water quality conditions monitored in the Niobrara River near Verdel, Nebraska (i.e., site GPTNFNIOR1) during the 3-year period 2008 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	19	2,220	1,950	753	3,950	-----	-----	-----
Water Temperature (°C)	0.1	19	19.3	21.7	0.4	30.8	29(1,2,6)	1	5%
Dissolved Oxygen (mg/l)	0.1	18	9.6	8.9	7.5	14.7	5(1,7)	0	0%
Dissolved Oxygen (% Sat.)	0.1	18	105.5	104.3	91.2	126.0	-----	-----	-----
pH (S.U.)	0.1	18	8.4	8.4	7.5	8.9	6.5(1,7), 9.0(1,6)	0	0%
Specific Conductance (umhos/cm)	1	19	300	298	222	390	2,000(4)	0	0%
Oxidation-Reduction Potential	1	18	342	345	181	491	-----	-----	-----
Alkalinity, Total (mg/l)	7	19	133	132	121	161	-----	0	0%
Carbon, Total Organic (mg/l)	0.05	19	5.3	4.9	1.8	11.6	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	19	22	20	6	38	-----	-----	-----
Chloride (mg/l)	1	14	3	3	2	6	-----	-----	-----
Chlorophyll *a* (ug/l)	1	8	42	32	n.d.	111	-----	-----	-----
Color (S.U. - APHA)	1	13	16	15	6	29	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	19	205	204	138	262	-----	-----	-----
Hardness, Total (mg/l)	1	2	146	146	126	165	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	19	-----	0.02	n.d.	0.26	3.9 (1,8,10), 0.81 (1,8,10)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	19	1.1	1.0	0.4	2.1	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	19	0.66	0.60	n.d.	1.80	10(3,6), 100(4,6)	0	0%
Nitrogen, Total (mg/l)	0.1	19	1.8	1.7	1.1	3.1	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	17	0.05	0.05	n.d.	0.12	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	19	0.27	0.28	0.14	0.55	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	19	-----	0.05	n.d.	0.14	-----	-----	-----
Sulfate (mg/l)	1	19	25	24	15	62	-----	-----	-----
Suspended Solids, Total (mg/l)	4	19	197	173	66	560	-----	-----	-----
Turbidity (NTU)	1	18	151	103	40	491	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	2	-----	84	n.d.	167	750(10), 87(11)	0, 1	0%, 50%
Antimony, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	0.7	88(10), 30(11), 6(12)	0	0%
Arsenic, Dissolved (ug/l)	1	2	5	5	4	6	340(10), 16.7(11), 10(12)	0	0%
Barium, Dissolved (ug/l)	5	2	112	112	111	112	2,000(11)	0	0%
Beryllium, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	130(10), 5.3(11), 4(12)	0	0%
Cadmium, Dissolved (ug/l)	0.2	2	-----	n.d.	n.d.	n.d.	8.5(10), 0.32(11), 5(12)	0, 1, 0	0%, 13%, 0%
Chromium, Dissolved (ug/l)	10	2	-----	n.d.	n.d.	n.d.	807(10), 105(11), 100(12)	0	0%
Copper, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	19(10), 12(11), 1,000(12)	0	0%
Iron, Dissolved (ug/l)	7	12	-----	20	n.d.	184	1,000(11)	0	0%
Lead, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	97(10), 3.8.2(11), 15(12)	0	0%
Manganese, Dissolved (ug/l)	2	12	-----	n.d.	n.d.	175	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	2	-----	n.d.	n.d.	n.d.	1.4(10)	0	0%
Mercury, Total (ug/l)	0.05	2	-----	n.d.	n.d.	n.d.	0.77(11), 2(12)	0	0%
Nickel, Dissolved (ug/l)	10	2	-----	n.d.	n.d.	n.d.	645(10), 72(11), 100(12)	0	0%
Selenium, Total (ug/l)	1	2	3	3	3	3	20(4,10), 5(11), 50(12)	0	0%
Silver, Dissolved (ug/l)	1	2	-----	n.d.	n.d.	n.d.	6.6(10), 100(12)	0	0%
Thallium, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	1,400(10), 6.3(11), 2(12)	0	0%
Zinc, Dissolved (ug/l)	5	2	-----	n.d.	n.d.	n.d.	161(10,11), 5,000(12)	0	0%
Acetochlor, Total (ug/l)(D)	0.05	2	-----	n.d.	n.d.	n.d.	-----	-----	-----
Atrazine, Total (ug/l)(D)	0.05	2	-----	0.15	n.d.	0.30	330(10), 12(11), 3(12)	0	0%
Metolachlor, Total (ug/l)(D)	0.05	2	-----	n.d.	n.d.	n.d.	390(10), 100(11)	0	0%
THM Formation Potential, Total	4	7	156	152	98	220	-----	-----	-----
Pesticide Scan (ug/l)(E)	0.05(F)	1	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) Nebraska's temperature criterion is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (11) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (12) Criterion for the protection of human health.

Note: Some of Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

(F) Detection limits vary by pesticide – 0.05 ug/l is a median detection limit for the pesticides in the pesticide scan.

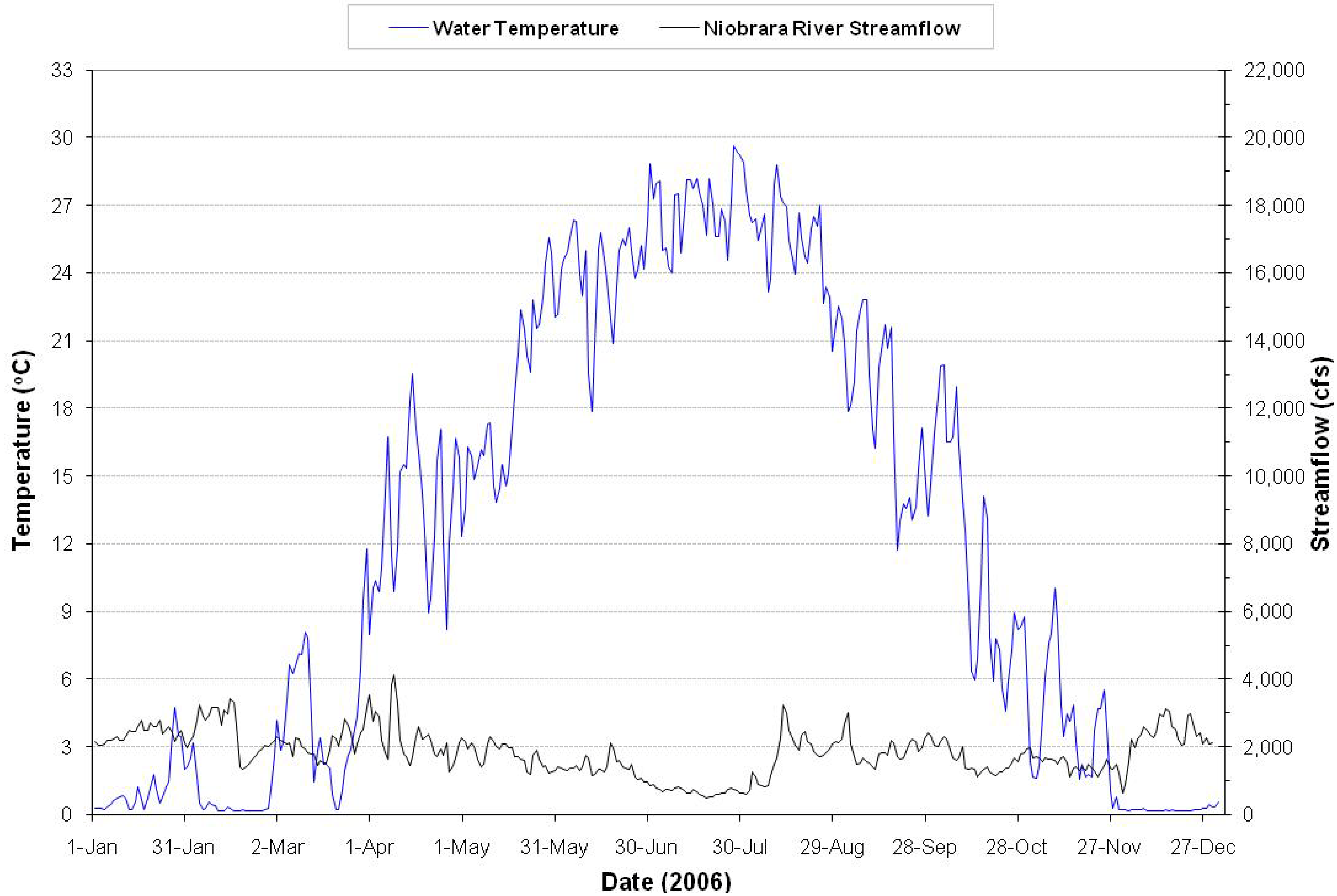

Plate 381. Mean daily water temperature and streamflow of the Niobrara River near Verdel, Nebraska (i.e., site USGS 06465500) for 2006.

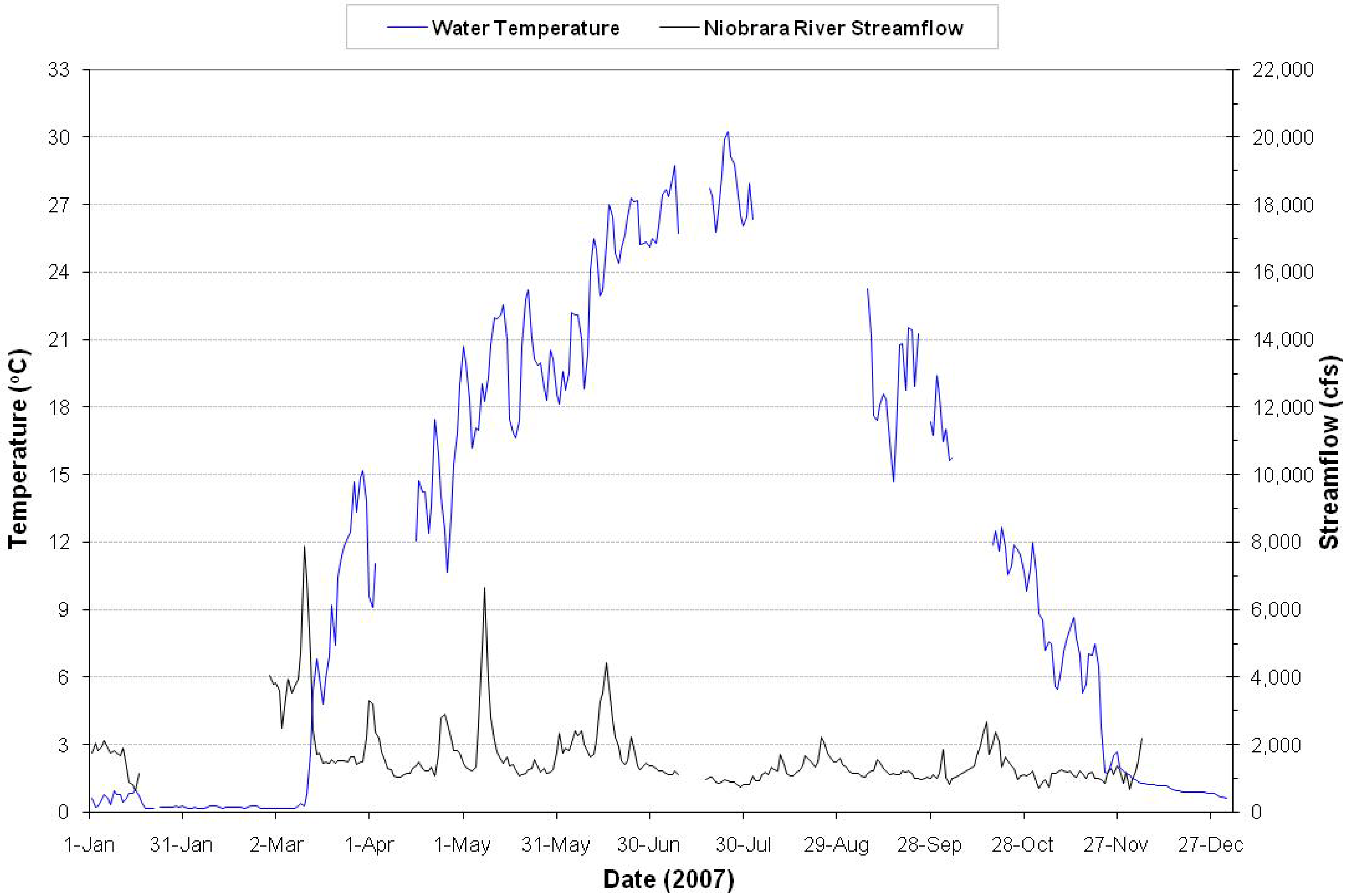

Plate 382. Mean daily water temperature and streamflow of the Niobrara River near Verdel, Nebraska (i.e., site USGS 06465500) for 2007.

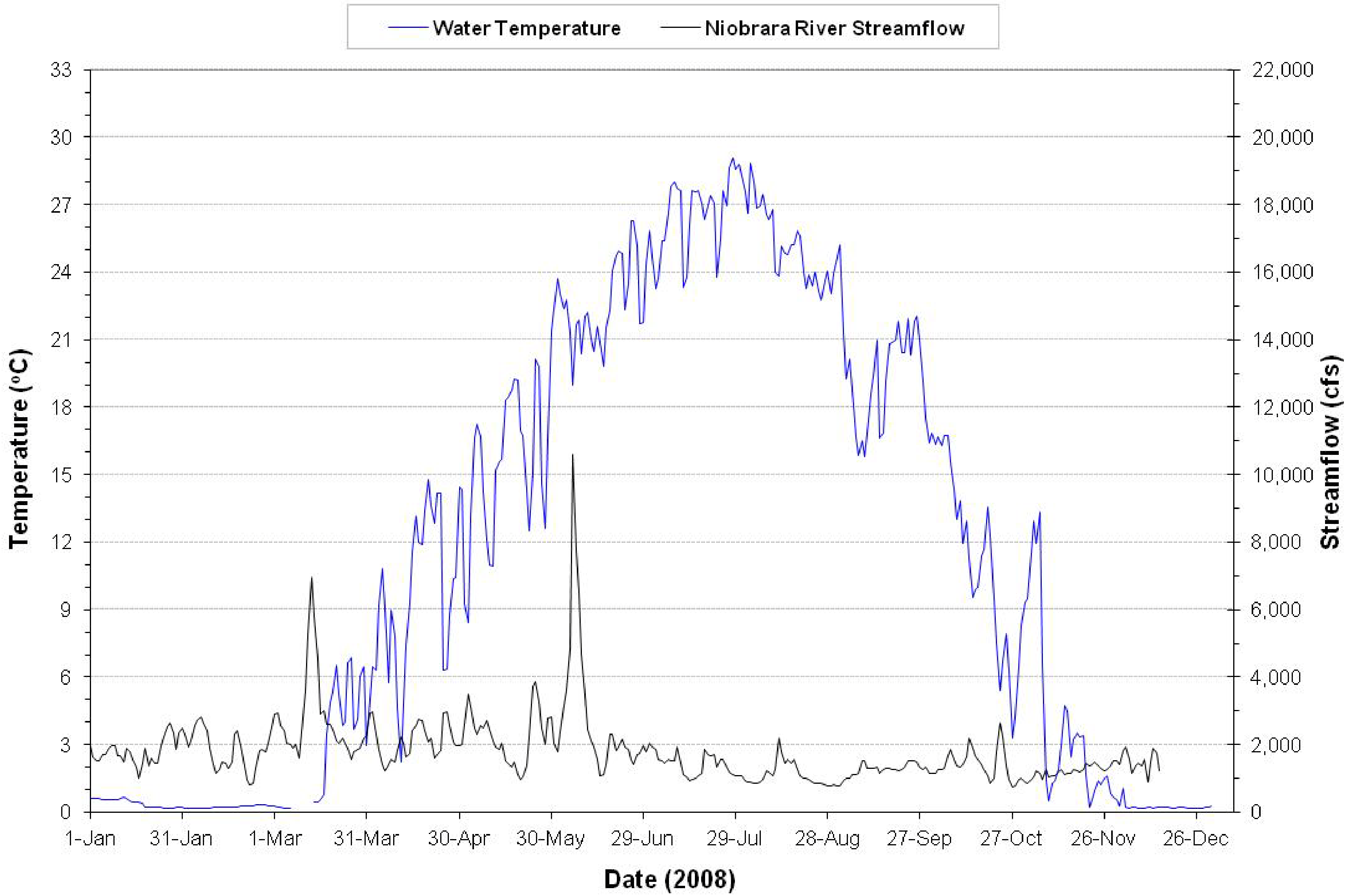

Plate 383. Mean daily water temperature and streamflow of the Niobrara River near Verdel, Nebraska (i.e., site USGS 06465500) for 2008.

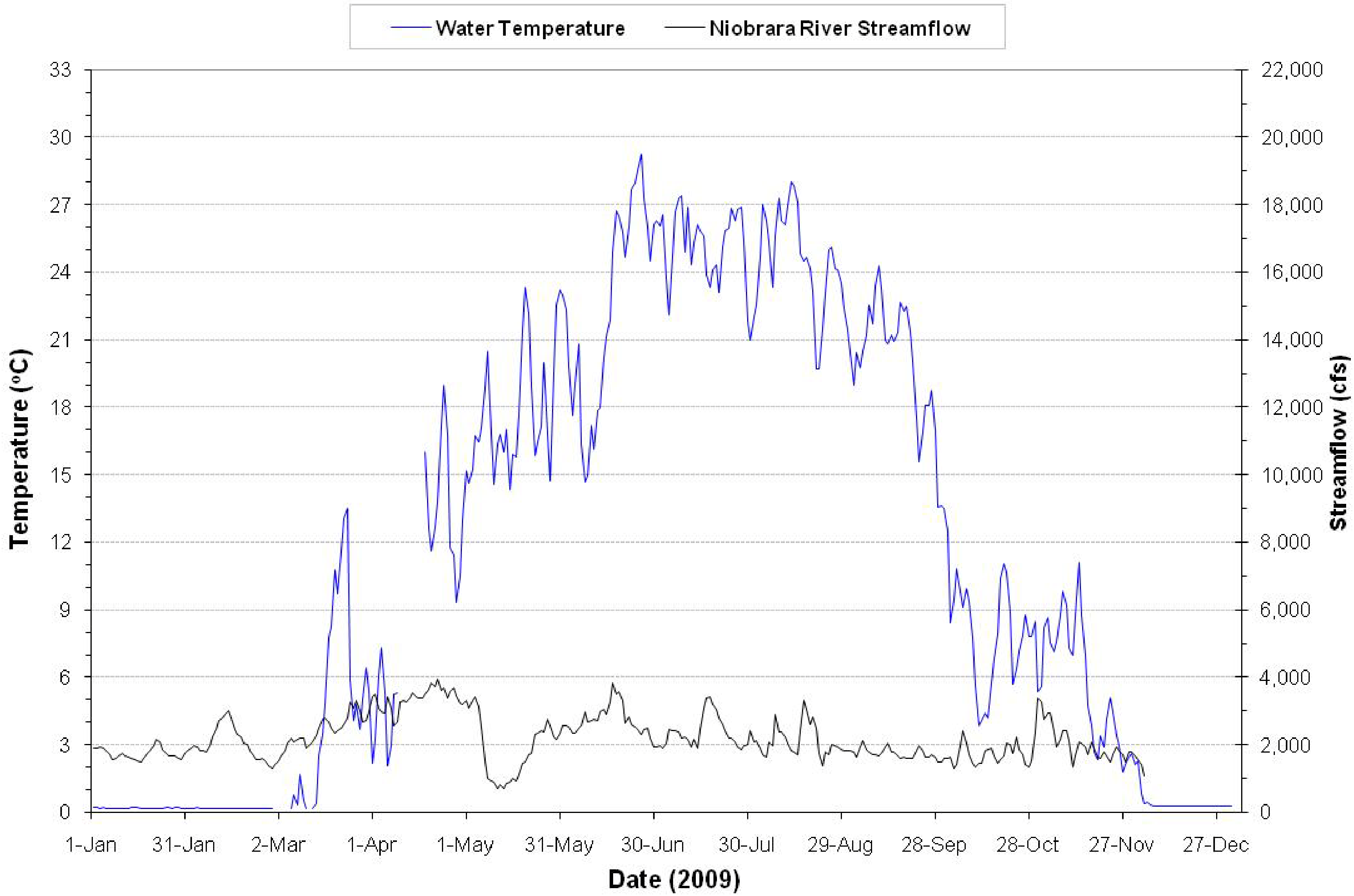

Plate 384. Mean daily water temperature and streamflow of the Niobrara River near Verdel, Nebraska (i.e., site USGS 06465500) for 2009.

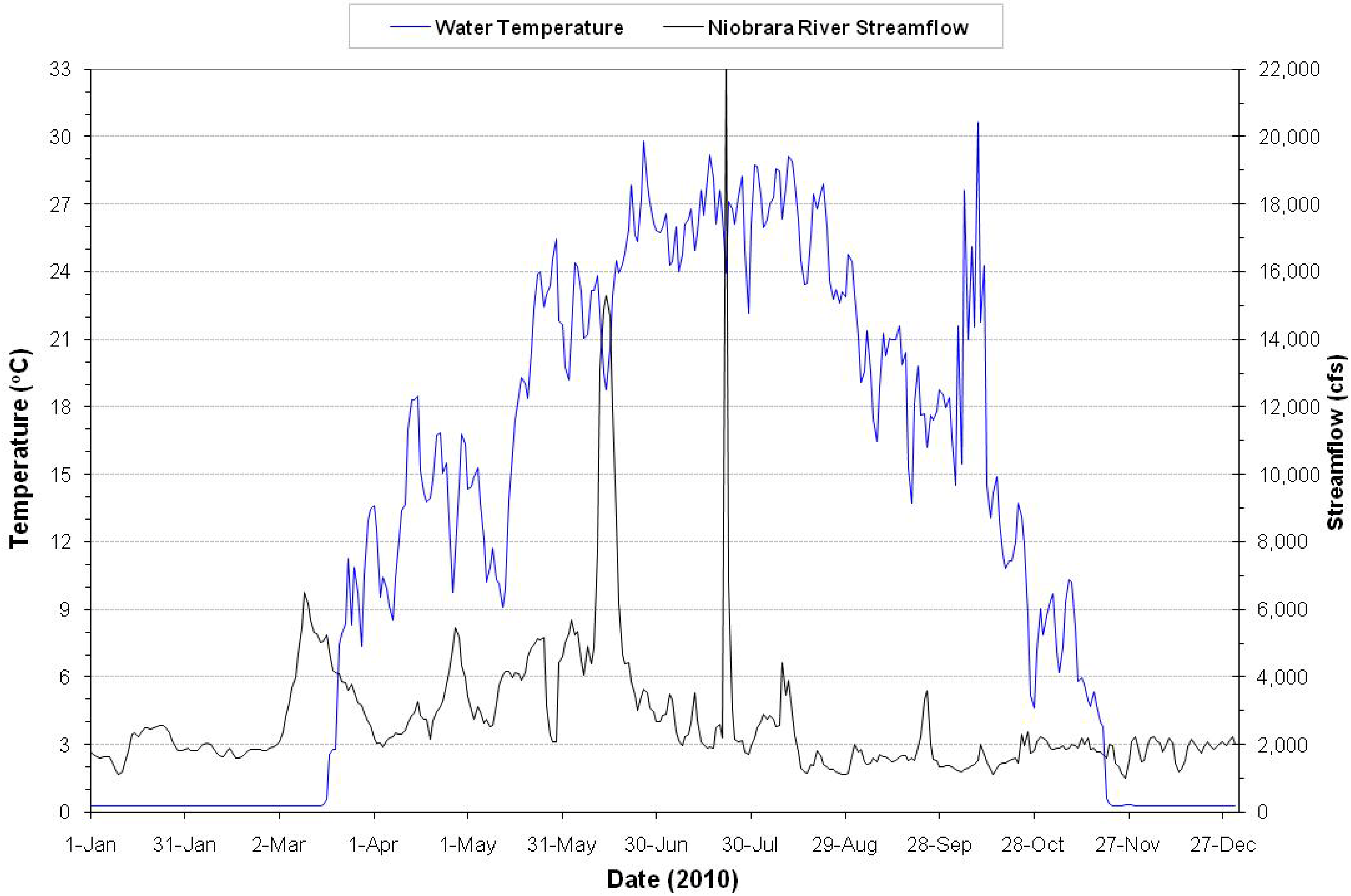

Plate 385. Mean daily water temperature and streamflow of the Niobrara River near Verdel, Nebraska (i.e., site USGS 06465500) for 2010.

Plate 386. Summary of near-surface water quality conditions monitored in the Missouri River near Running Water, South Dakota (i.e., site GPTNFMORR1) at RM841 during 2009 and 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Streamflow (cfs)	1	16	31,499	28,948	15,562	50,456	-----	-----	-----
Water Temperature (°C)	0.1	15	13.6	13.9	1.1	27.2	27[1,2,6], 29[1,2,6]	0, 1	0%, 7%
Dissolved Oxygen (mg/l)	0.1	15	9.9	10.0	6.9	13.4	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	15	95.5	95.8	85.5	106.0	-----	-----	-----
pH (S.U.)	0.1	15	8.2	8.2	7.5	8.5	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Specific Conductance (umhos/cm)	1	15	644	653	420	770	2,000[4]	0	0%
Oxidation-Reduction Potential	1	14	344	356	206	420	-----	-----	-----
Alkalinity, Total (mg/l)	7	16	145	146	132	156	-----	0	0%
Carbon, Total Organic (mg/l)	0.05	16	4.1	3.8	2.0	9.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	16	13	12	6	27	-----	-----	-----
Chloride (mg/l)	1	10	10	10	8	13	438[3,6], 250[3,8]	0	0%
Chlorophyll *a* (ug/l)	1	14	11	6	n.d.	42	-----	-----	-----
Color (S.U. - APHA)	1	15	10	9	5	31	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	16	437	428	314	622	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	0	0%
Hardness, Total (mg/l)	1	5	205	190	182	238	-----	-----	-----
Nitrogen, Ammonia Total (mg/l)	0.02	16	-----	0.03	n.d.	0.28	5.7 [1,6,9], 1.1 [1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	16	0.7	0.5	0.2	1.3	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	16	0.38	0.30	n.d.	1.00	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/l)	0.1	16	1.0	0.8	0.5	2.3	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	12	0.03	0.03	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	16	0.10	0.08	n.d.	0.33	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	16	-----	0.03	n.d.	0.09	-----	-----	-----
Suspended Solids, Total (mg/l)	4	16	53	33	4	180	158[1,6], 90[1,8]	1, 2	6%, 13%
THM Formation Potential, Total	4	13	218	200	74	464	-----	-----	-----
Turbidity (NTU)	1	15	42	25	n.d.	213	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	5	-----	n.d.	n.d.	n.d.	750[10], 87[11], 200[12]	0	0%
Antimony, Dissolved (ug/l)	0.5	5	-----	n.d.	n.d.	n.d.	88[10], 30[11], 6[12]	0	0%
Arsenic, Dissolved (ug/l)	1	5	2	2	2	3	340[10], 16.7[11], 10[12]	0	0%
Barium, Dissolved (ug/l)	5	5	54	54	37	75	2,000[11]	0	0%
Beryllium, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	130[10], 5.3[11], 4[12]	0	0%
Cadmium, Dissolved (ug/l)	0.2	5	-----	n.d.	n.d.	n.d.	3.8[10], 0.38[11], 5[12]	0	0%
Chromium, Dissolved (ug/l)	10	5	-----	n.d.	n.d.	n.d.	964[10], 125[11], 100[12]	0	0%
Copper, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	25[10], 16[11], 1,000[12]	0	0%
Iron, Dissolved (ug/l)	7	5	9	10	8	10	1,000[11]	0	0%
Lead, Dissolved (ug/l)	0.5	5	-----	n.d.	n.d.	n.d.	129[10], 5.0[11], 15[12]	0	0%
Manganese, Dissolved (ug/l)	2	5	20	18	n.d.	40	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	5	-----	n.d.	n.d.	n.d.	1.4[10]	0	0%
Mercury, Total (ug/l)	0.05	5	-----	n.d.	n.d.	n.d.	0.77[11], 2[12]	0	0%
Nickel, Dissolved (ug/l)	10	5	-----	n.d.	n.d.	n.d.	806[10], 90[11], 100[12]	0	0%
Selenium, Total (ug/l)	1	5	3	3	2	4	20[4,10], 5[11], 50[12]	0	0%
Silver, Dissolved (ug/l)	1	5	-----	n.d.	n.d.	n.d.	9.7[10], 100[12]	0	0%
Thallium, Dissolved (ug/l)	0.5	5	-----	n.d.	n.d.	n.d.	1,400[10], 6.3[11], 2[12]	0	0%
Zinc, Dissolved (ug/l)	5	5	-----	n.d.	n.d.	n.d.	202[10,11], 5,000[12]	0	0%
Pesticide Scan (ug/l)[D]	0.05[E]	2	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.

[A] Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- [2] South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- [3] Criteria for the protection of domestic water supply waters.
- [4] Criteria for the protection of agricultural water supply waters.
- [5] Criteria for the protection of commerce and industry waters.
- [6] Daily maximum criterion (monitoring results directly comparable to criterion).
- [7] Daily minimum criterion (monitoring results directly comparable to criterion).
- [8] 30-day average criterion (monitoring results not directly comparable to criterion).
- [9] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- [10] Acute (CMC) criterion for the protection of freshwater aquatic life.
- [11] Chronic (CCC) criterion for the protection of freshwater aquatic life.
- [12] Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] Immunoassay analysis.

[E] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

[F] Detection limits vary by pesticide – 0.05 ug/l is a median detection limit for the pesticides in the pesticide scan.

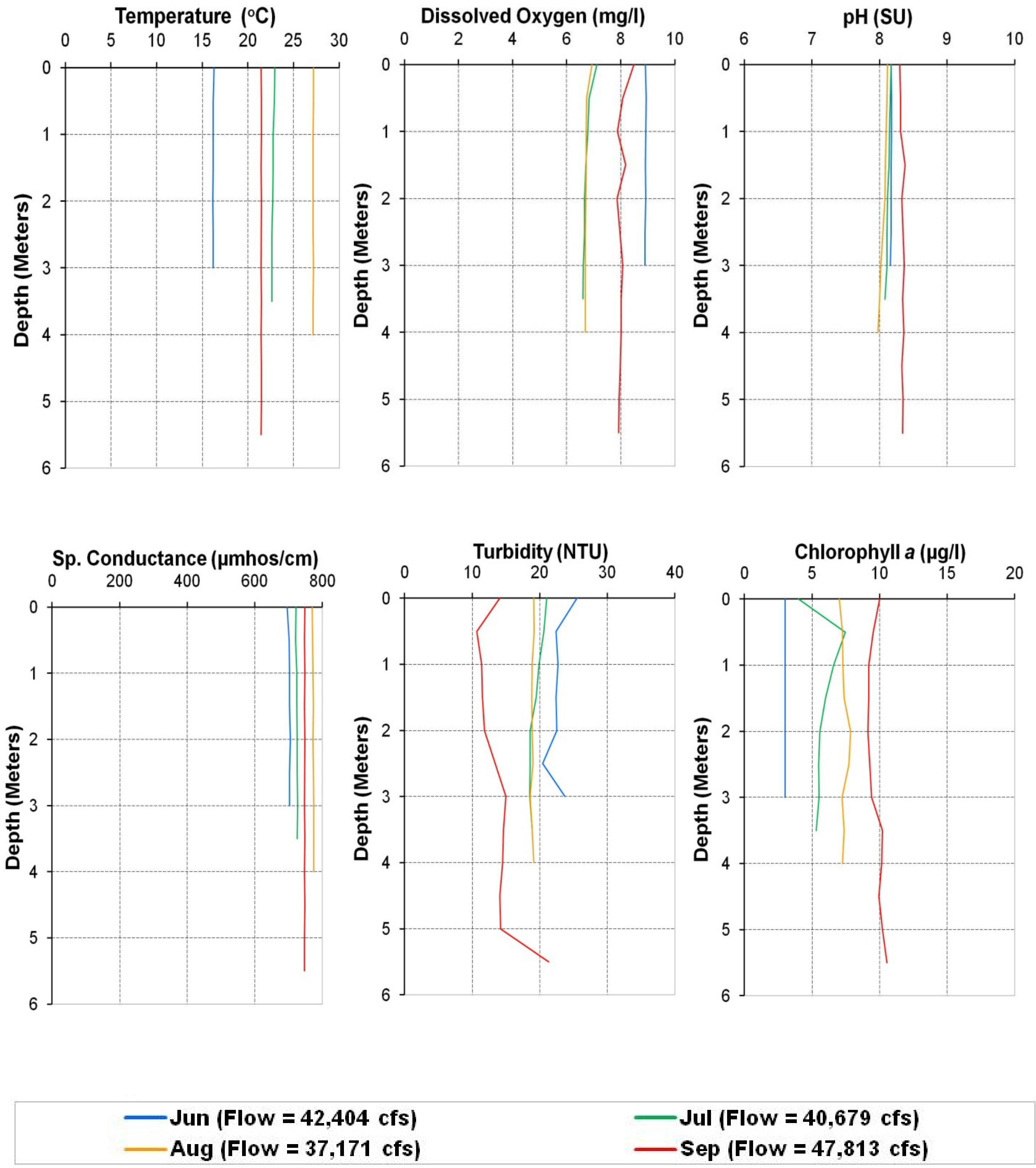

Plate 387. Water temperature, dissolved oxygen, pH, specific conductance, turbidity, and chlorophyll *a* depth profiles for the Missouri River compiled from data collected at the Lewis and Clark Lake inflow site (i.e., GPTPNFMORR1) during 2010.

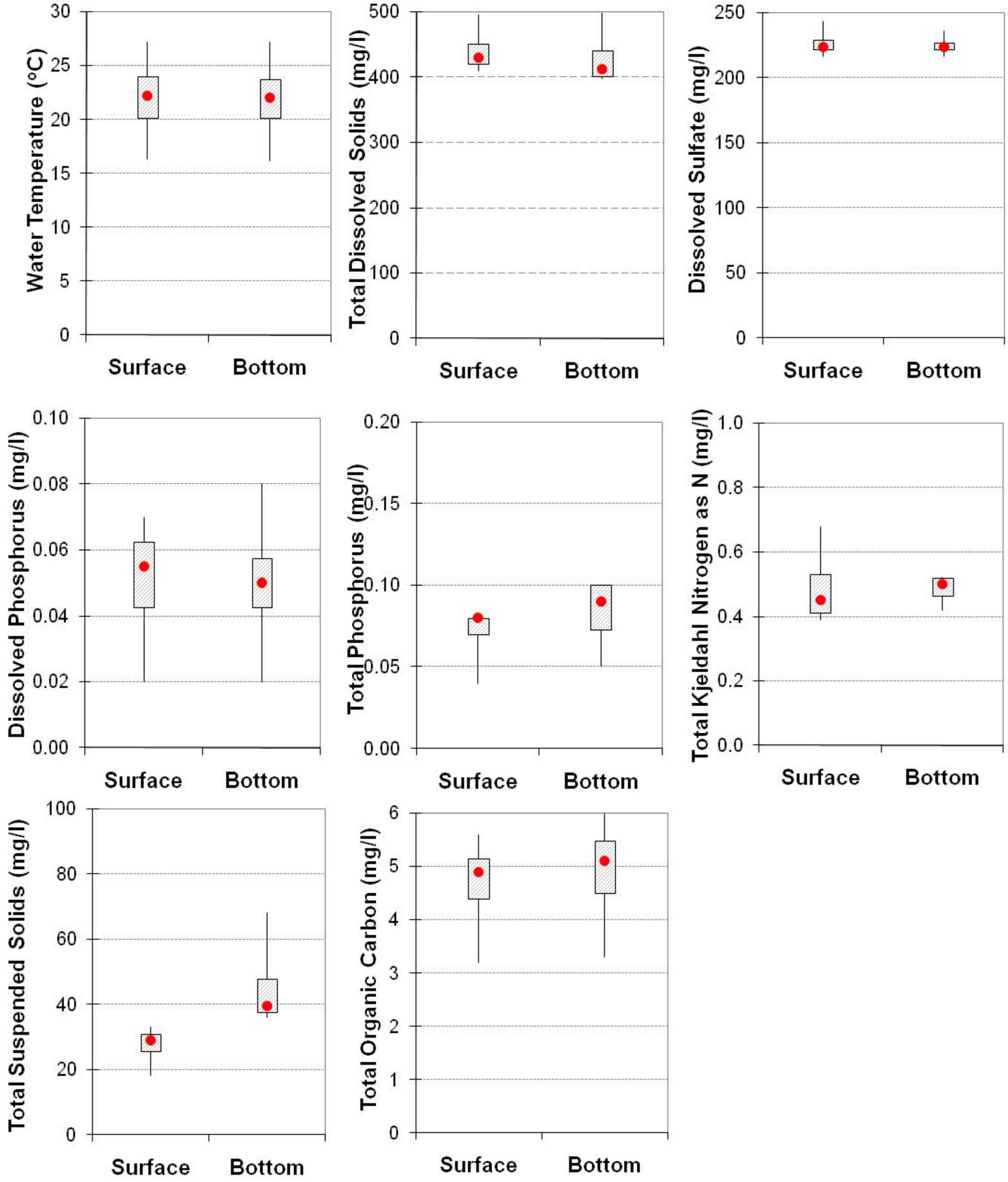

Plate 388. Box plots comparing paired surface and bottom water temperature, total dissolved solids, dissolved sulfate, dissolved phosphorus, total phosphorus, total Kjeldahl nitrogen, total suspended solids, and total organic carbon measurements taken in the Missouri River at site GPTNFMORR1 during 2010. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

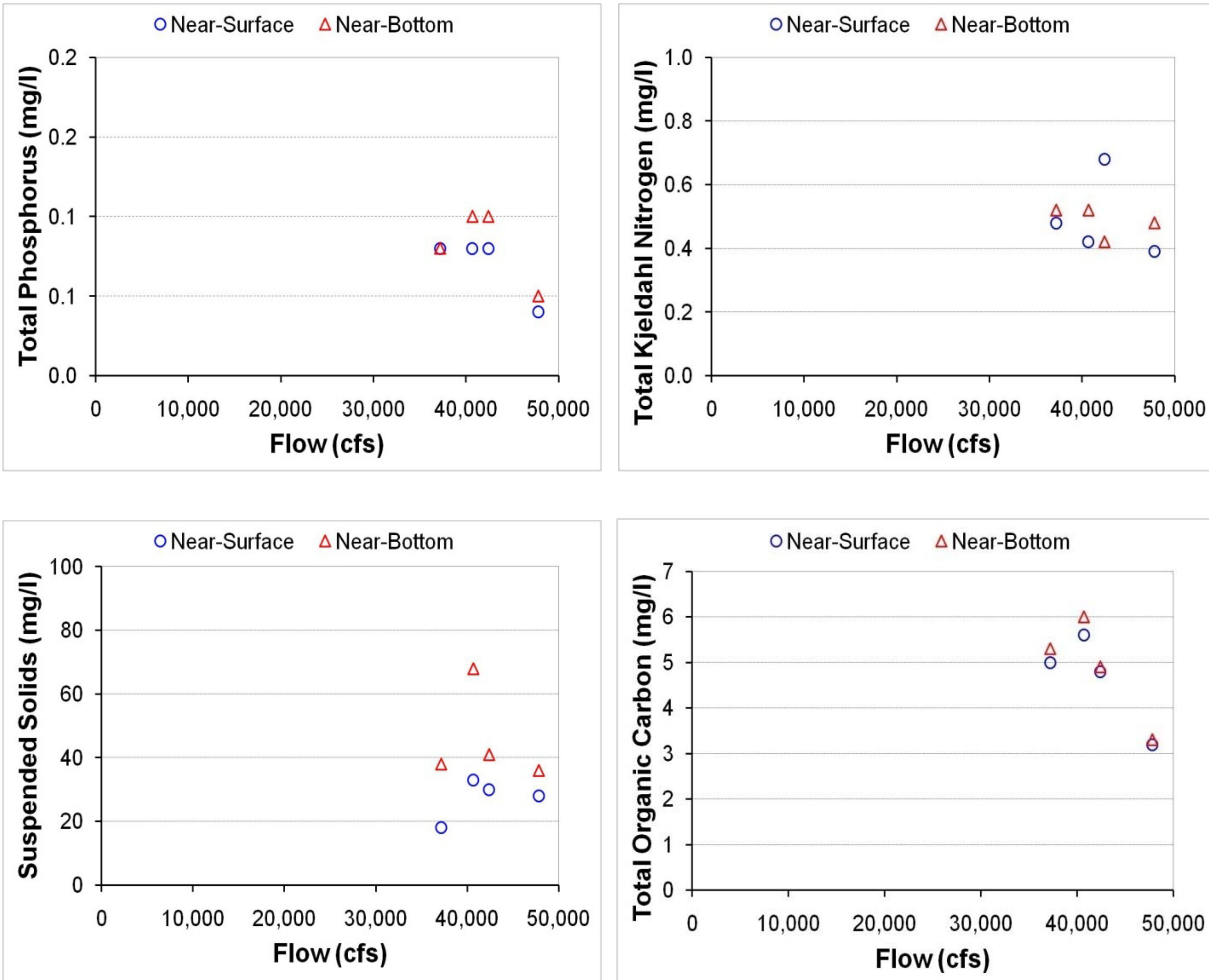

Plate 389. Comparison of flow and measured near-surface and near-bottom concentrations of total phosphorus, total Kjeldahl nitrogen, total suspended solids, and total organic carbon in the Missouri River near Running Water, SD (i.e., site GPTNFMORR1).

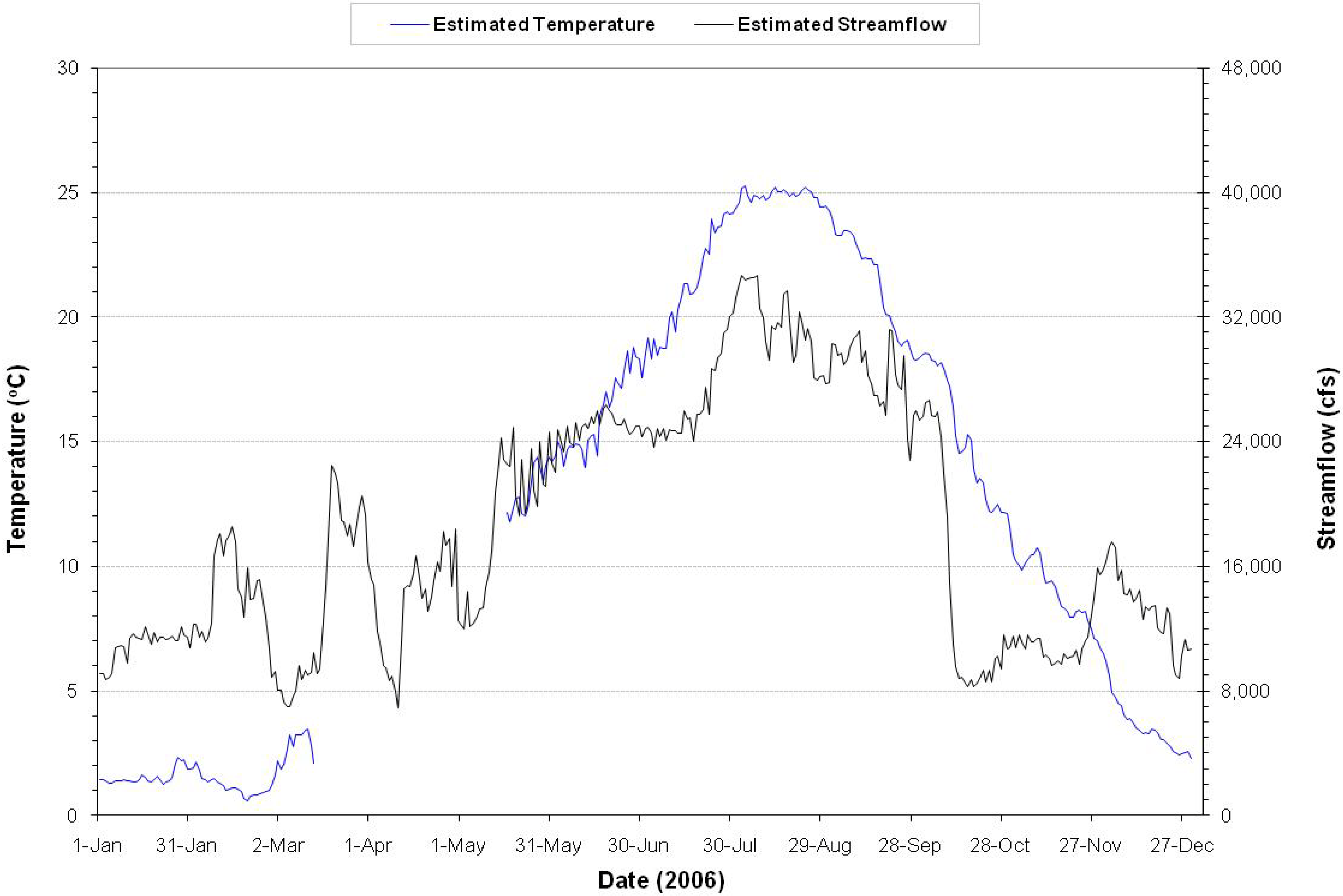

Plate 390. Mean daily water temperature and streamflow estimated for the Missouri River inflow to Lewis and Clark Lake for 2006. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, Nebraska at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites.

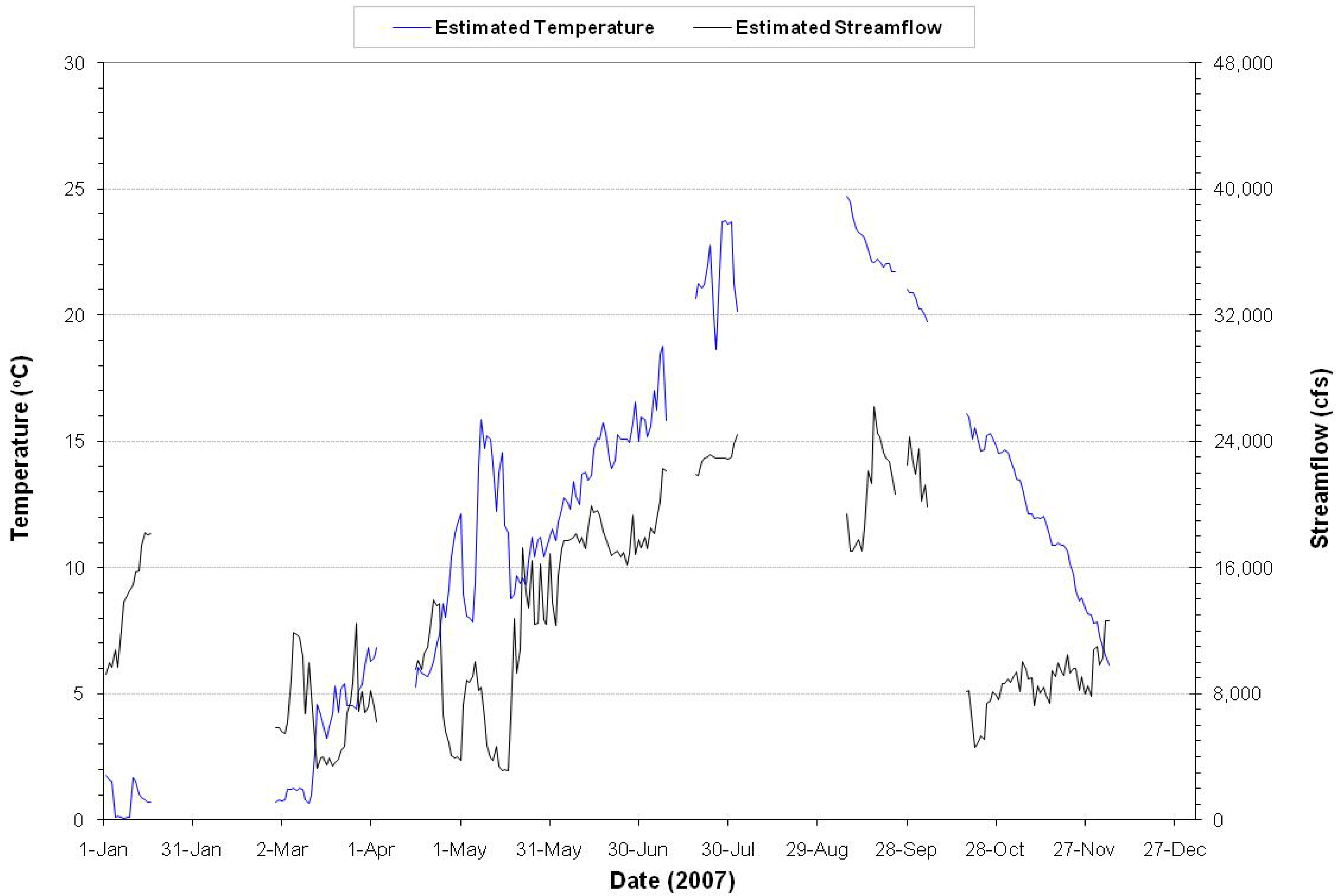

Plate 391. Mean daily water temperature and streamflow estimated for the Missouri River inflow to Lewis and Clark Lake for 2007. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, Nebraska at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites. (Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

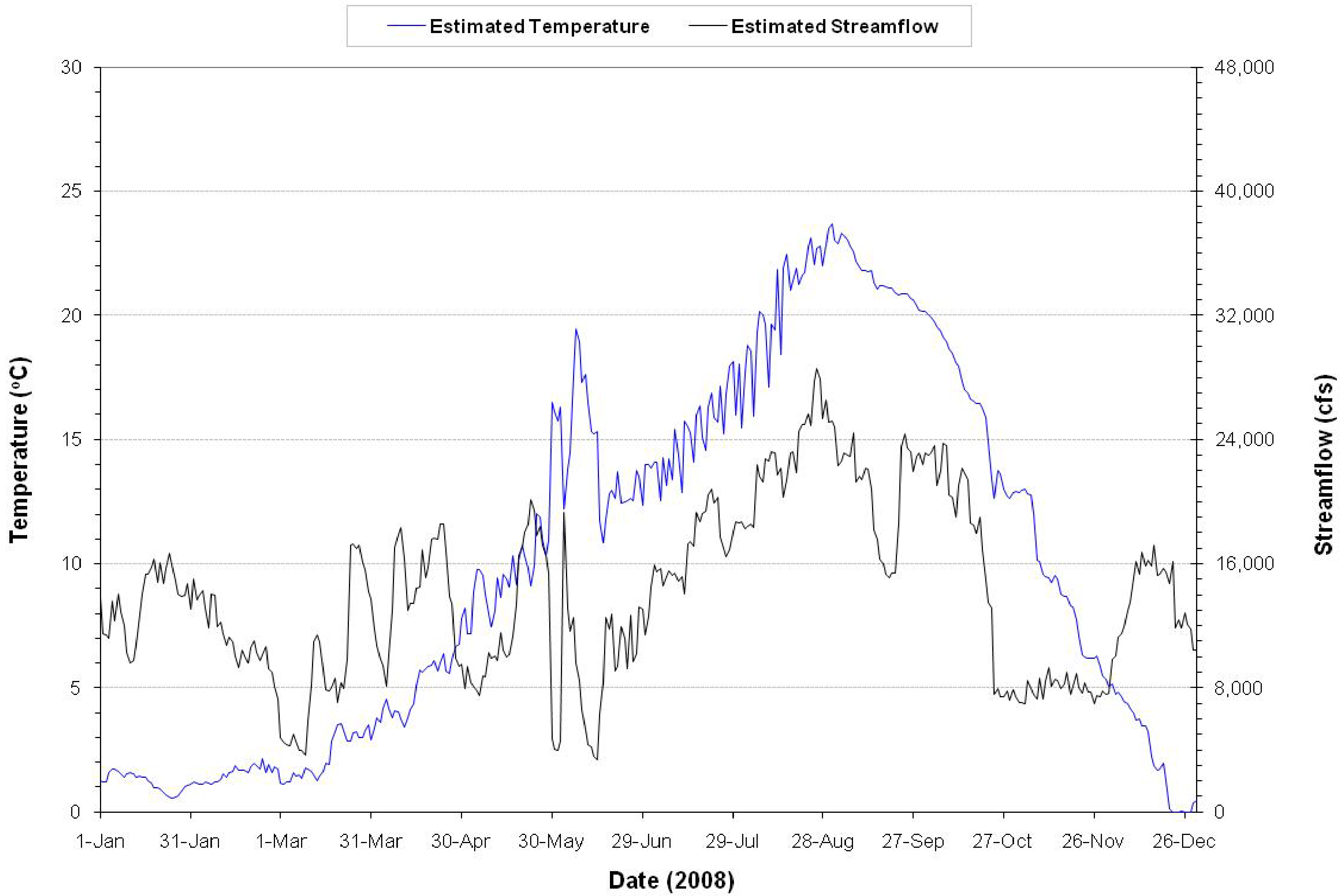

Plate 392. Mean daily water temperature and streamflow estimated for the Missouri River inflow to Lewis and Clark Lake for 2008. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, Nebraska at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites.

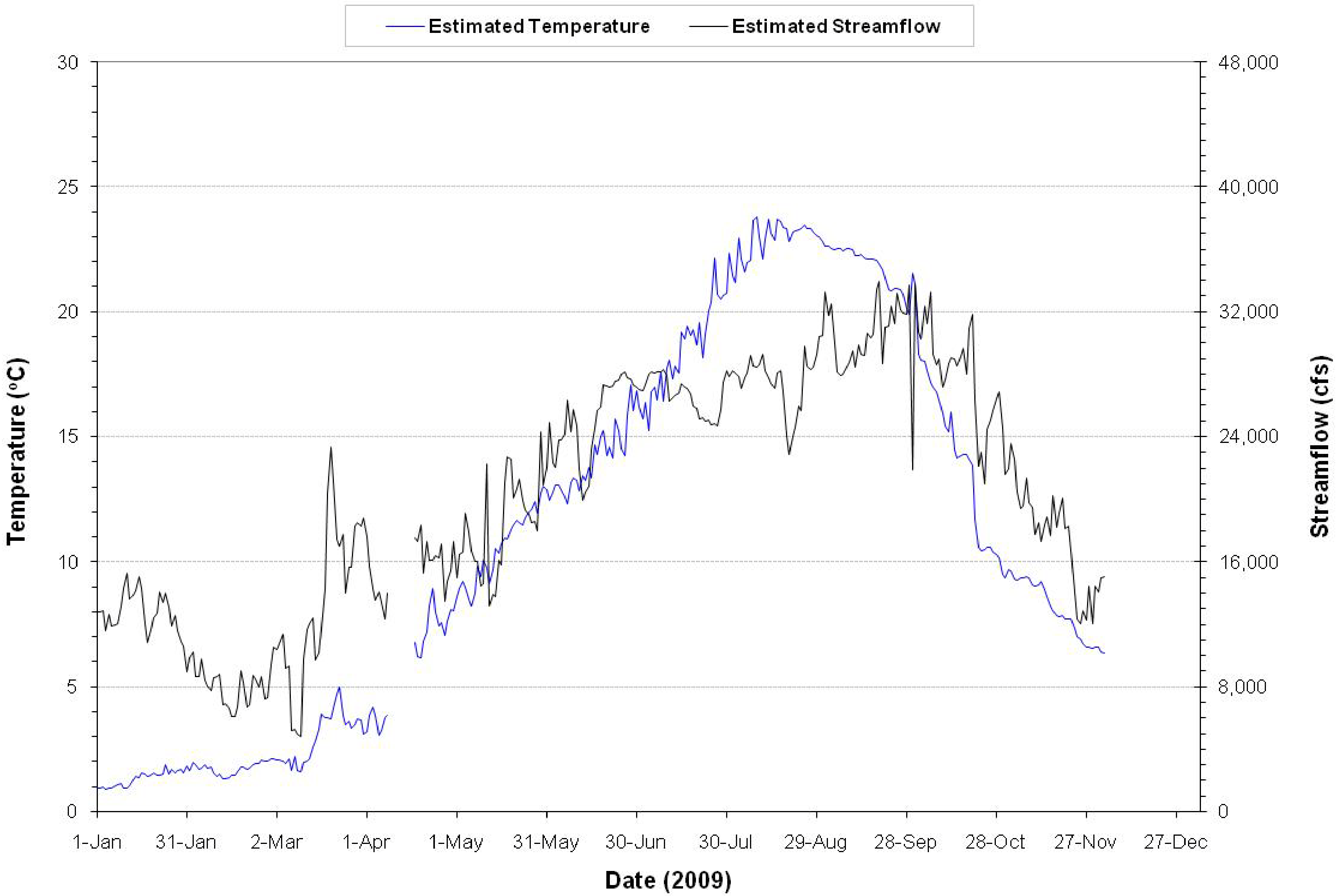

Plate 393. Mean daily water temperature and streamflow estimated for the Missouri River inflow to Lewis and Clark Lake for 2009. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, Nebraska at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites.

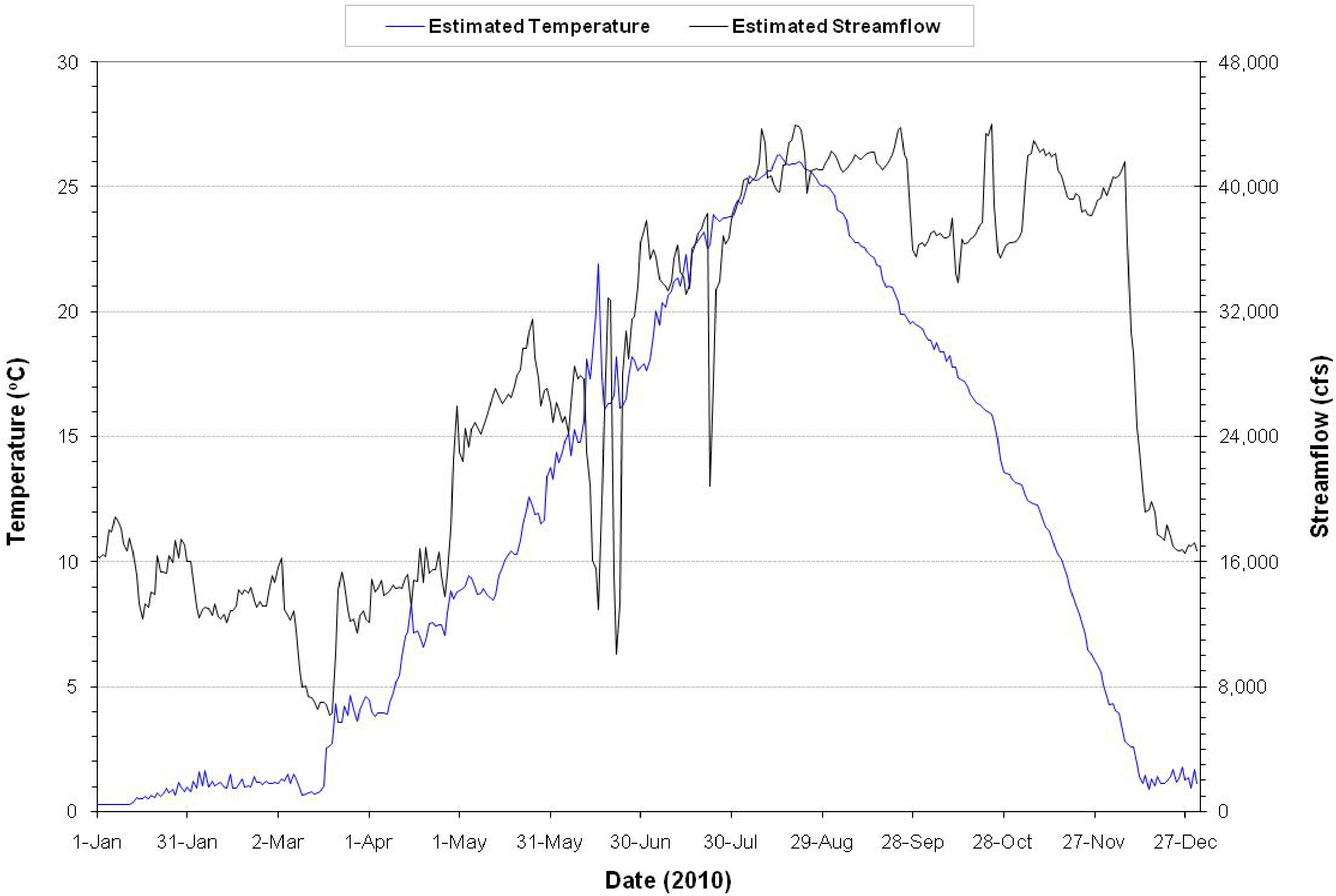

Plate 394. Mean daily water temperature and streamflow estimated for the Missouri River inflow to Lewis and Clark Lake for 2010. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, Nebraska at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites.

Plate 395. Summary of water quality conditions monitored on water discharged through Gavins Point Dam (i.e., site GPTPP1) during the 5-year period of 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Dam Discharge (cfs)	1	50	19,249	17,036	8,000	49,065	-----	-----	-----
Water Temperature (°C)	0.1	49	13.6	14.3	0.3	26.3	27(1,2,6), 29(1,2,6)	0	0%
Dissolved Oxygen (mg/l)	0.1	48	10.0	9.7	2.6	13.9	5(1,7)	1	2%
Dissolved Oxygen (% Sat.)	0.1	48	97.1	97.6	20.1	121.6	-----	-----	-----
pH (S.U.)	0.1	47	8.3	8.3	7.1	8.9	6.5(1,3,7), 9.0(1,3,6), 9.5(5,6)	0	0%
Specific Conductance (umhos/cm)	1	48	683	697	482	762	2,000(4)	-----	-----
Oxidation-Reduction Potential (mV)	1	41	351	361	148	464	-----	-----	-----
Turbidity (NTU)	1	40	34	10	n.d.	824	-----	-----	-----
Alkalinity, Total (mg/l)	7	50	156	156	129	197	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	49	3.8	3.2	1.2	13.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	50	12	11	n.d.	35	-----	-----	-----
Chloride, Dissolved (mg/l)	1	39	11	11	8	19	438(3,6), 250(3,8)	0	0%
Color (APHA)	1	9	9	8	6	12	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	50	446	451	310	522	1,750(2,4), 1,000(2,7), 3,500(3,4), 2,000(3,6)	0	0%
Nitrogen, Ammonia Total (mg/l)	0.02	50	-----	n.d.	n.d.	0.44	4.7(1,6,9), 1.4 (1,8,9)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	50	0.6	0.6	n.d.	1.8	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/l)	0.02	50	-----	0.07	n.d.	0.60	10(3,6), 100(4,6)	0	0%
Nitrogen, Total (mg/l)	0.1	50	0.8	.07	n.d.	2.3	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	47	-----	0.02	n.d.	0.30	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	50	0.06	0.05	n.d.	0.38	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	50	-----	n.d.	n.d.	0.19	-----	-----	-----
Sulfate (mg/l)	1	50	191	191	107	233	875(3,6), 500(3,8)	0	0%
Suspended Solids, Total (mg/l)	4	50	-----	9	n.d.	71	158(1,6), 90(1,8)	0	0%

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
(2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
(3) Criteria for the protection of domestic water supply waters.
(4) Criteria for the protection of agricultural water supply waters.
(5) Criteria for the protection of commerce and industry waters.
(6) Daily maximum criterion (monitoring results directly comparable to criterion).
(7) Daily minimum criterion (monitoring results directly comparable to criterion).
(8) 30-day average criterion (monitoring results not directly comparable to criterion).
(9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

Plate 396. Summary of annual metals and pesticide levels monitored on water discharged through Gavins Point Dam (i.e., site GPTPP1) during the 5-year period of 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Aluminum, Dissolved (ug/l)	25	4	-----	n.d.	n.d.	26	750[1], 87[2], 200[3]	0	0%
Aluminum, Total (ug/l)	25	4	323	268	200	556	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	0.8	88[1], 30[2], 6[3]	0	0%
Antimony, Total (ug/l)	0.5	4	-----	n.d.	n.d.	1.0	5.6[4]	0	0%
Arsenic, Dissolved (ug/l)	1	6	-----	2	n.d.	3	340[1], 16.7[2]	0	0%
Arsenic, Total (ug/l)	1	4	2	2	2	3	10[3], 0.018[4]	0, 4	0%, 100%
Barium, Dissolved (ug/l)	5	4	48	48	44	54	-----	-----	-----
Barium, Total (ug/l)	5	4	50	50	47	54	2,000[3]	0	0%
Beryllium, Dissolved (ug/l)	2	5	-----	n.d.	n.d.	n.d.	130[1], 5.3[2]	0	0%
Beryllium, Total (ug/l)	2	4	-----	n.d.	n.d.	n.d.	4[4]	0	0%
Cadmium, Dissolved (ug/l)	0.2	6	-----	n.d.	n.d.	n.d.	4.3[1], 0.43[2]	0	0%
Cadmium, Total (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	5[3,4]	0	0%
Chromium, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	n.d.	1,087[1], 141[2]	0	0%
Chromium, Total (ug/l)	10	4	-----	n.d.	n.d.	n.d.	100[3]	-----	-----
Copper, Dissolved (ug/l)	2	6	-----	7	n.d.	10	28[1], 18[2],	0	0%
Copper, Total (ug/l)	2	4	-----	5	n.d.	140	1,300[3,4]	0	0%
Hardness, Total (mg/l)	1	5	221	220	208	238	-----	-----	-----
Iron, Dissolved (ug/l)	40	16	-----	n.d.	n.d.	40	1,000[2]	0	0%
Iron, Total (ug/l)	40	16	391	247	70	1,620	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	151[1], 5.9[2]	0	0%
Lead, Total (ug/l)	0.5	4	-----	n.d.	n.d.	0.6	-----	-----	-----
Manganese, Dissolved (ug/l)	2	16	-----	4	n.d.	50	1,000[2]	0	0%
Manganese, Total (ug/l)	2	16	73	49	6	290	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	6	-----	n.d.	n.d.	n.d.	1.4[1]	0	0%
Mercury, Total (ug/l)	0.05	6	-----	n.d.	n.d.	n.d.	0.77[2], 0.05[3], 2[3]	0	0%
Nickel, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	n.d.	912[1], 101[2]	0	0%
Nickel, Total (ug/l)	10	4	-----	n.d.	n.d.	n.d.	610[4]	0	0%
Selenium, Total (ug/l)	1	4	-----	3	n.d.	5	20[1], 5[2], 50[3], 170[4]	0	0%
Silver, Dissolved (ug/l)	1	6	-----	n.d.	n.d.	n.d.	13[1]	0	0%
Silver, Total (ug/l)	1	4	-----	n.d.	n.d.	n.d.	10[3]	0	0%
Thallium, Dissolved (ug/l)	0.5	6	-----	n.d.	n.d.	n.d.	1,400[1], 6.3[2], 2[3], 0.24[3]	0	0%
Thallium, Total (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	0.24[3]	b.d.	b.d.
Zinc, Dissolved (ug/l)	10	6	-----	n.d.	n.d.	13	229[1,2]	0	0%
Zinc, Total (ug/l)	10	4	-----	n.d.	n.d.	33	5,000[4], 7,400[4]	0	0%
Pesticide Scan (ug/l)[D]	0.05[E]	5	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected, b.d. = Criterion below detection limit.

(A) Results for iron (dissolved and total) and manganese (dissolved and total) include some monthly samples.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Acute (CMC) criterion for the protection of freshwater aquatic life.

(2) Chronic (CCC) criterion for the protection of freshwater aquatic life.

(3) Criterion for the protection of domestic water supply waters.

(4) Criterion for the protection of human health.

Note: Some of South Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

(E) Detection limits vary by pesticide – 0.05 ug/l is a median detection limit for the pesticides in the pesticide scan.

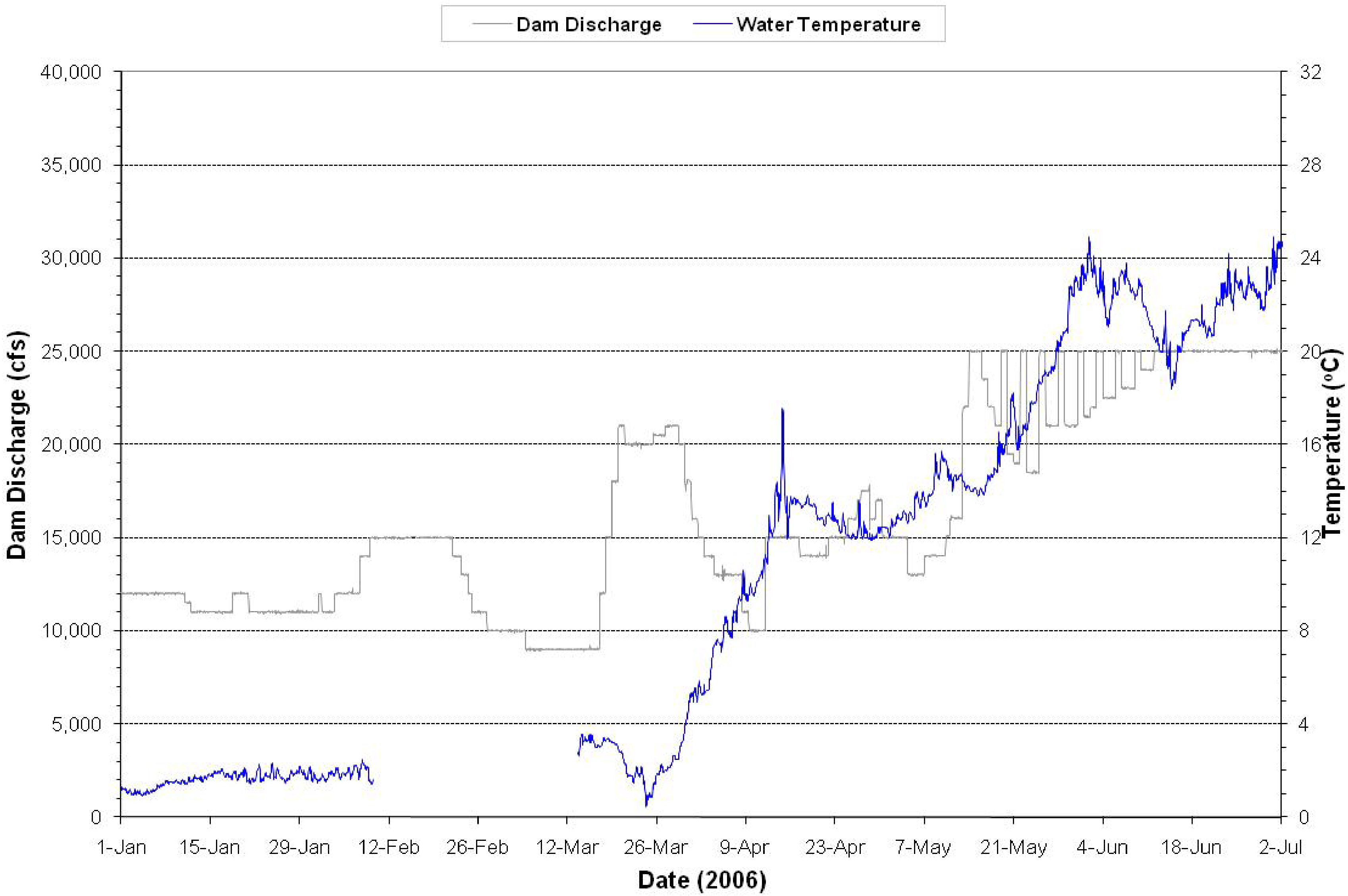

Plate 397. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the powerplant during the period January through June 2006.
Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.

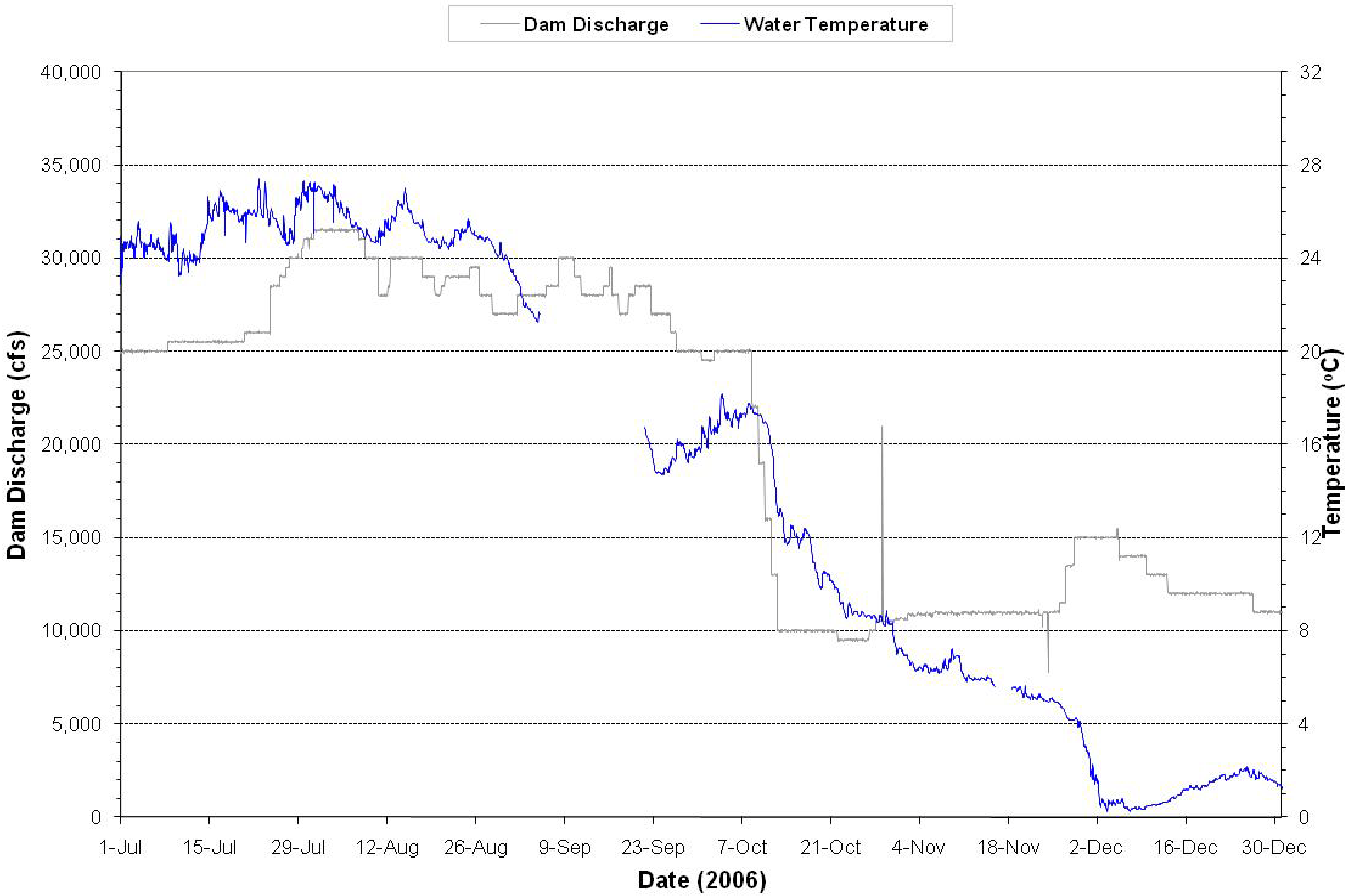

Plate 398. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the powerplant during the period July through December 2006.
Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.

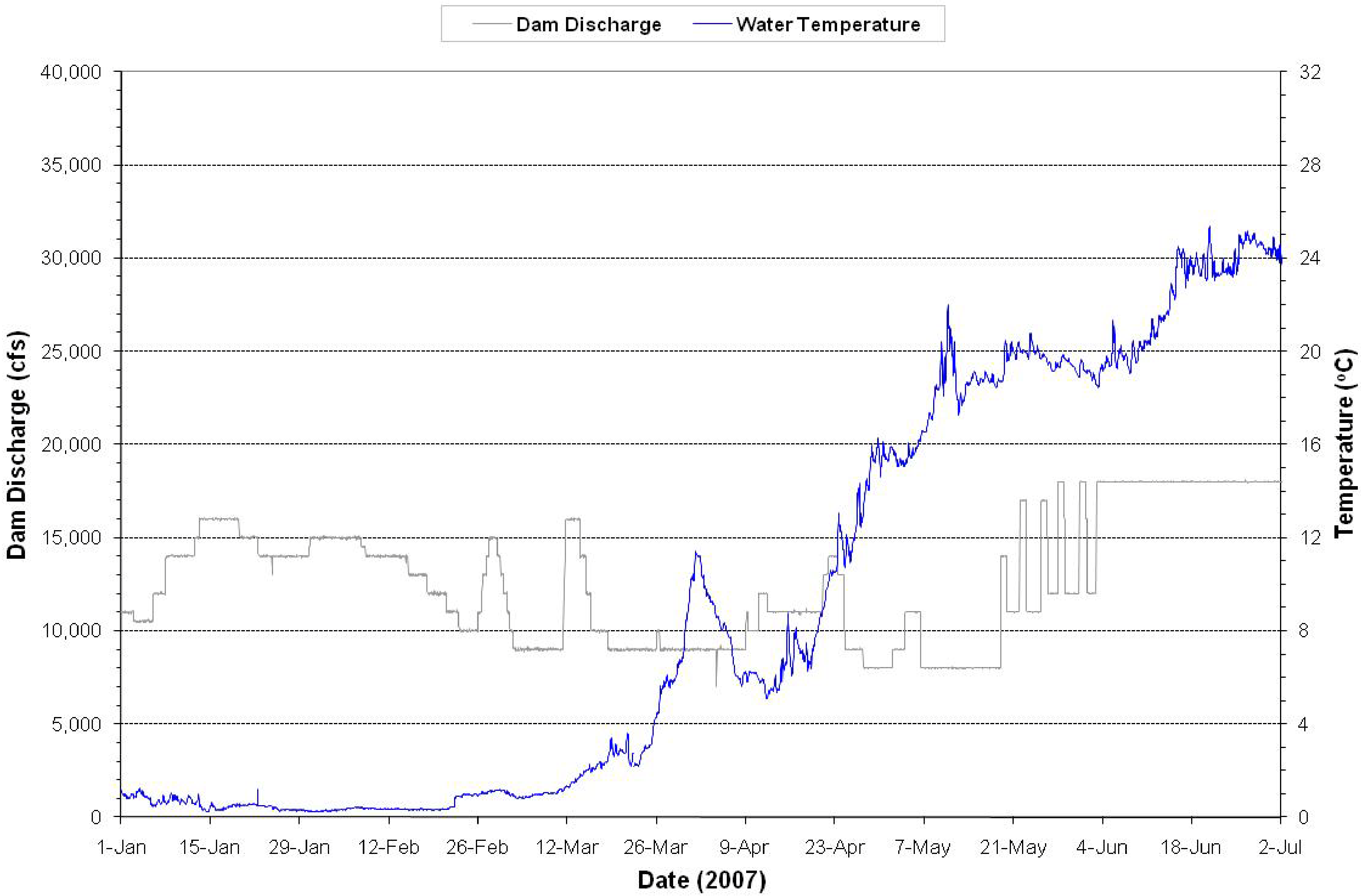

Plate 399. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the powerplant during the period January through June 2007.

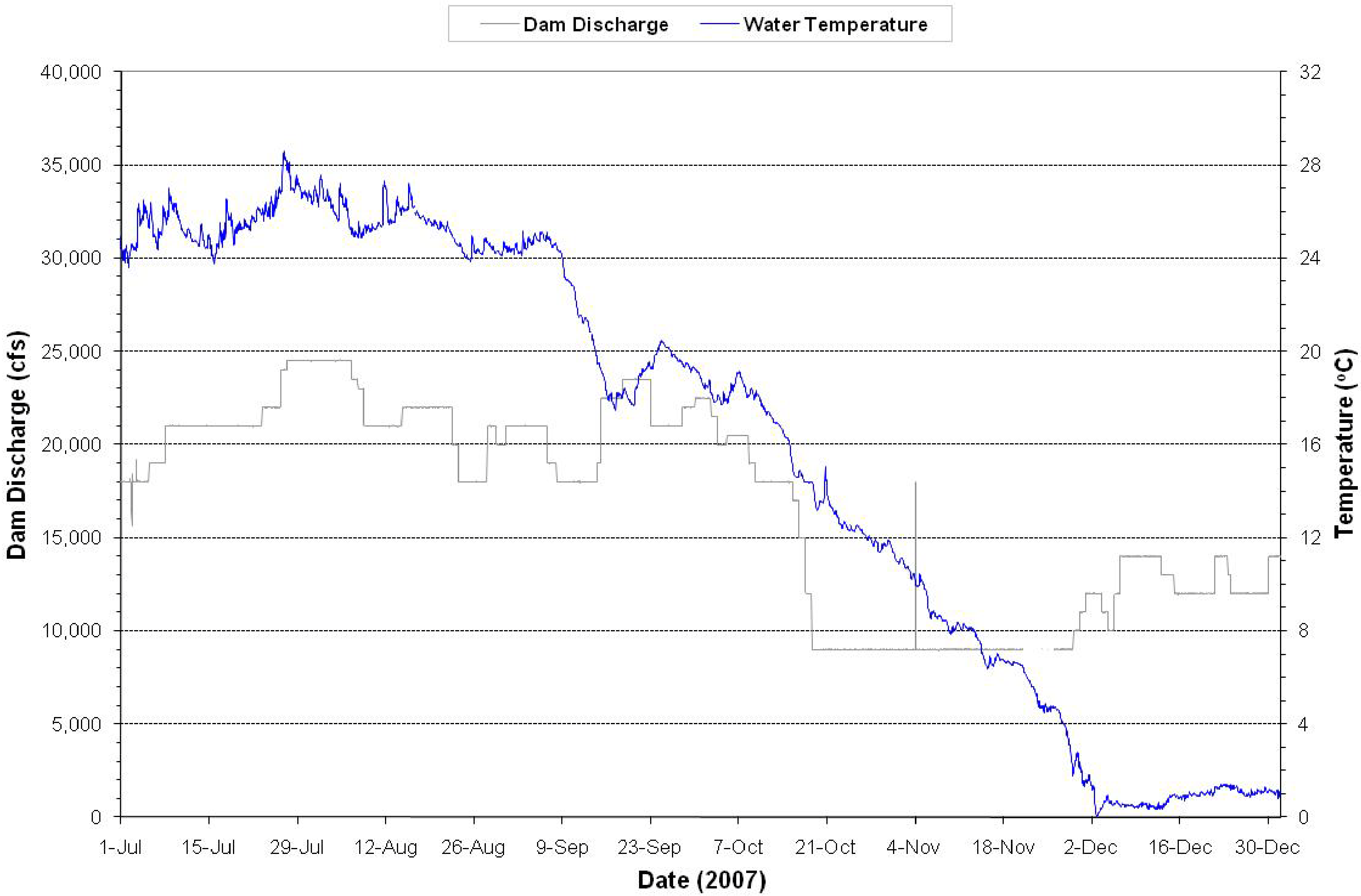

Plate 400. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the powerplant during the period July through December 2007.

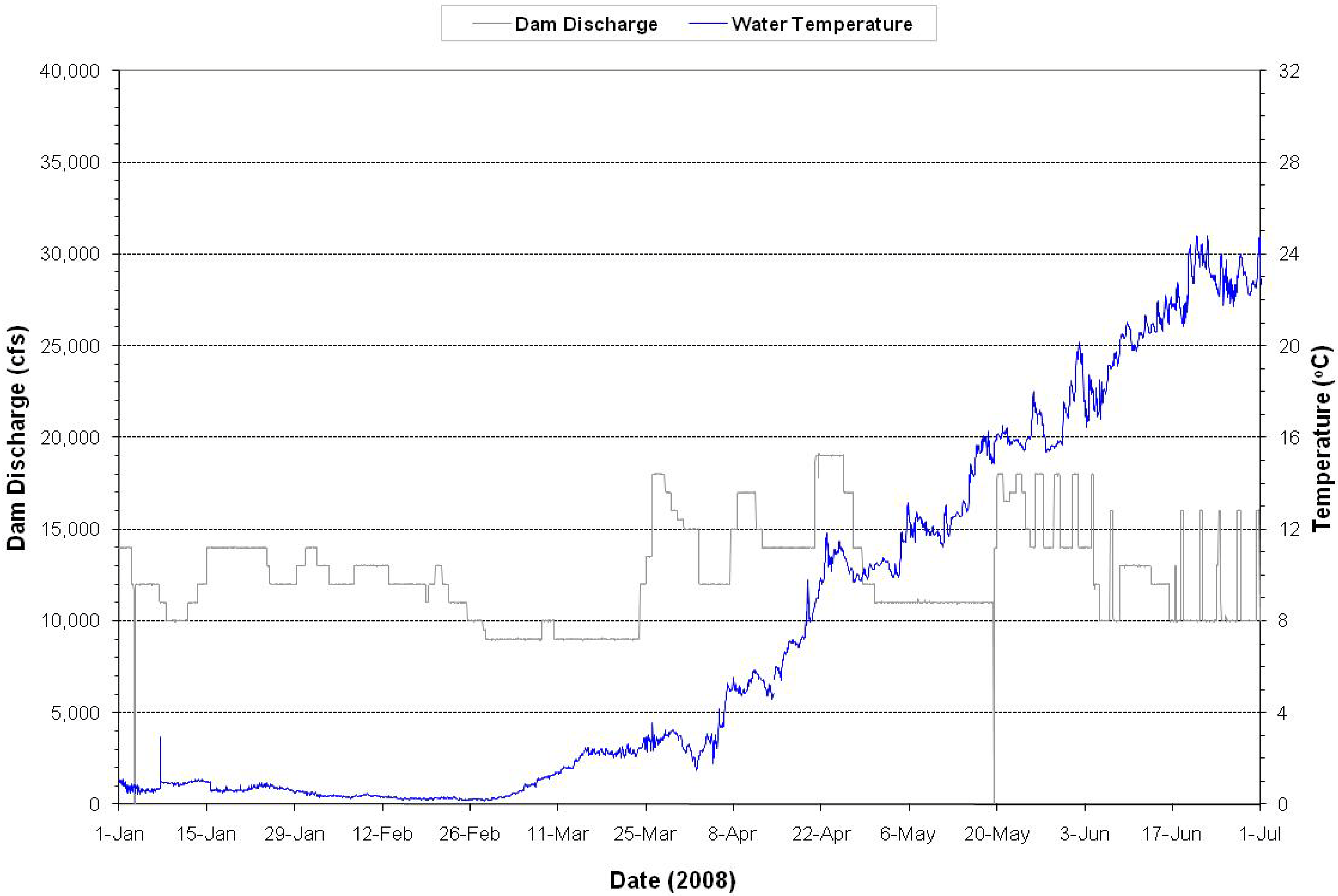

Plate 401. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the powerplant during the period January through June 2008.

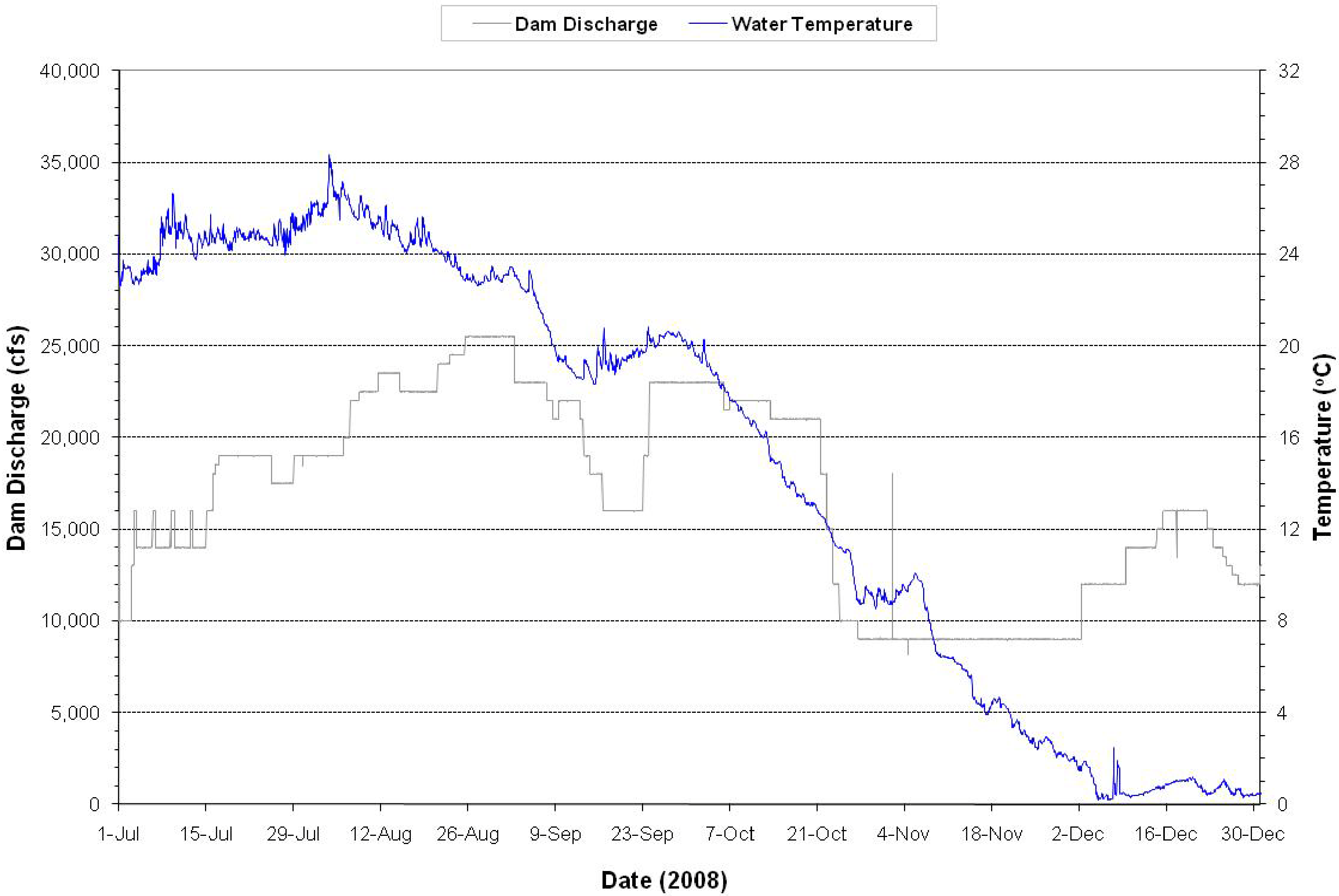

Plate 402. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the powerplant during the period July through December 2008.

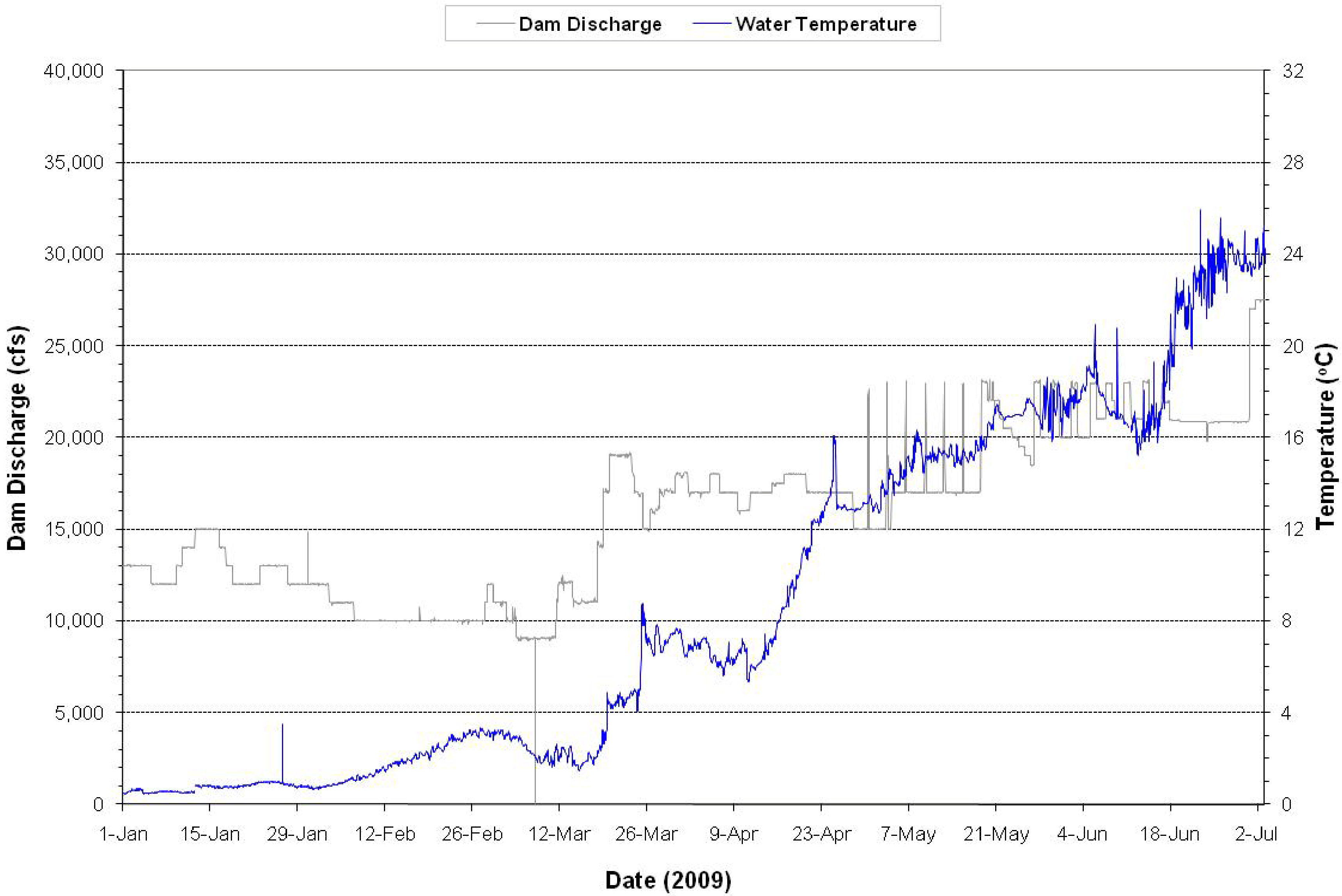

Plate 403. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the powerplant during the period January through June 2009.

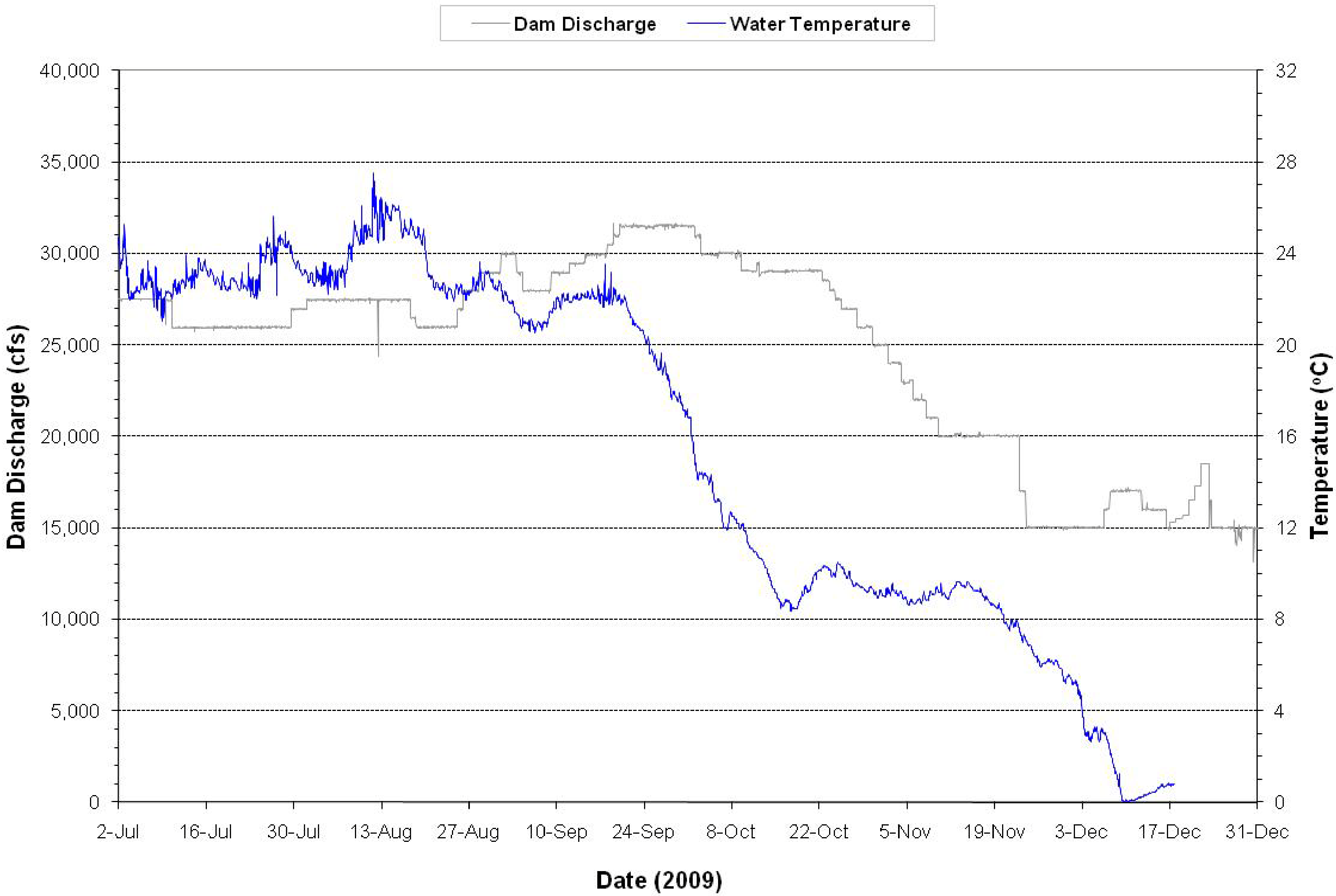

Plate 404. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the powerplant during the period July through December 2009.

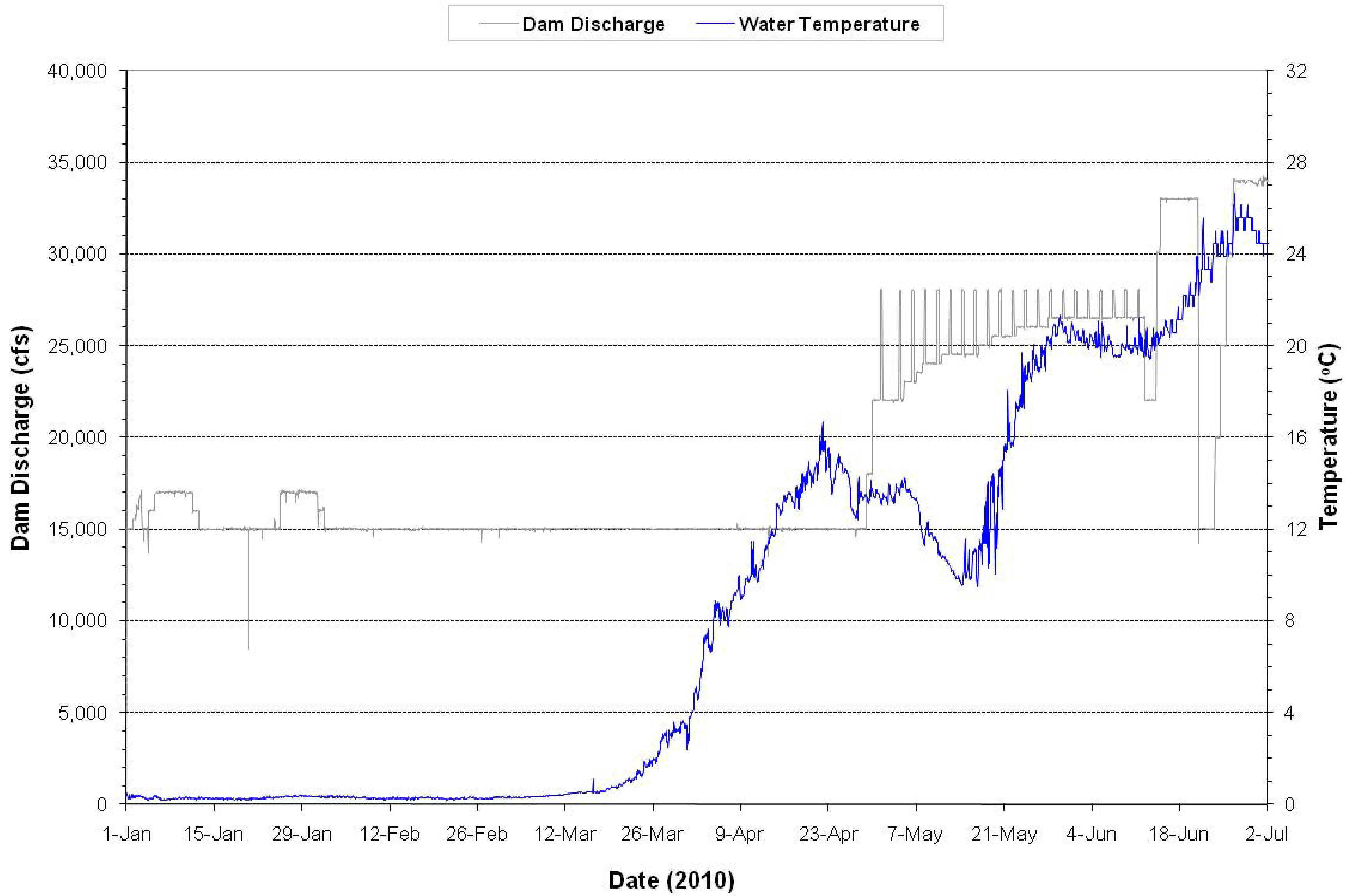

Plate 405. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the powerplant during the period January through June 2010.

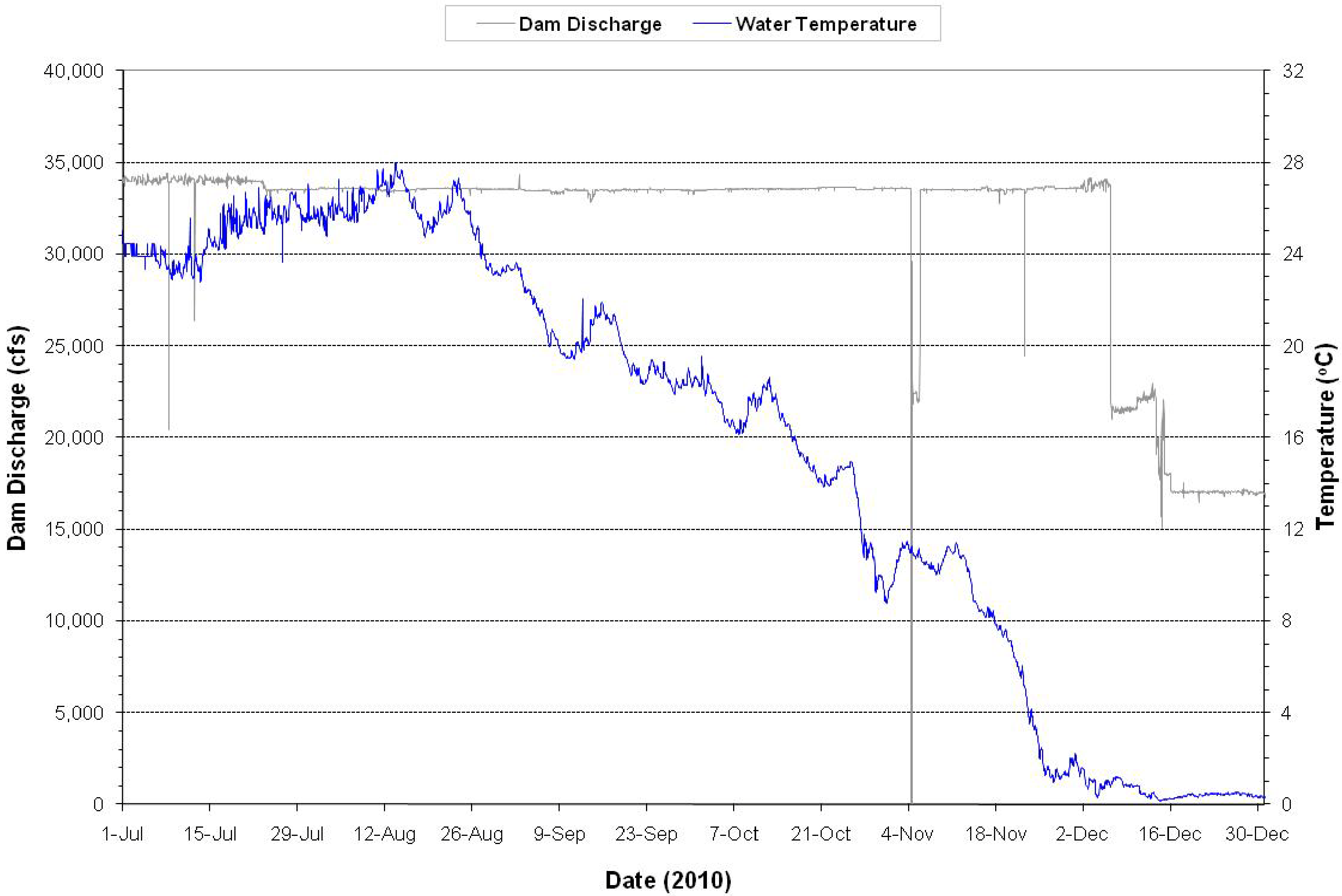

Plate 406. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the powerplant during the period July through December 2009.

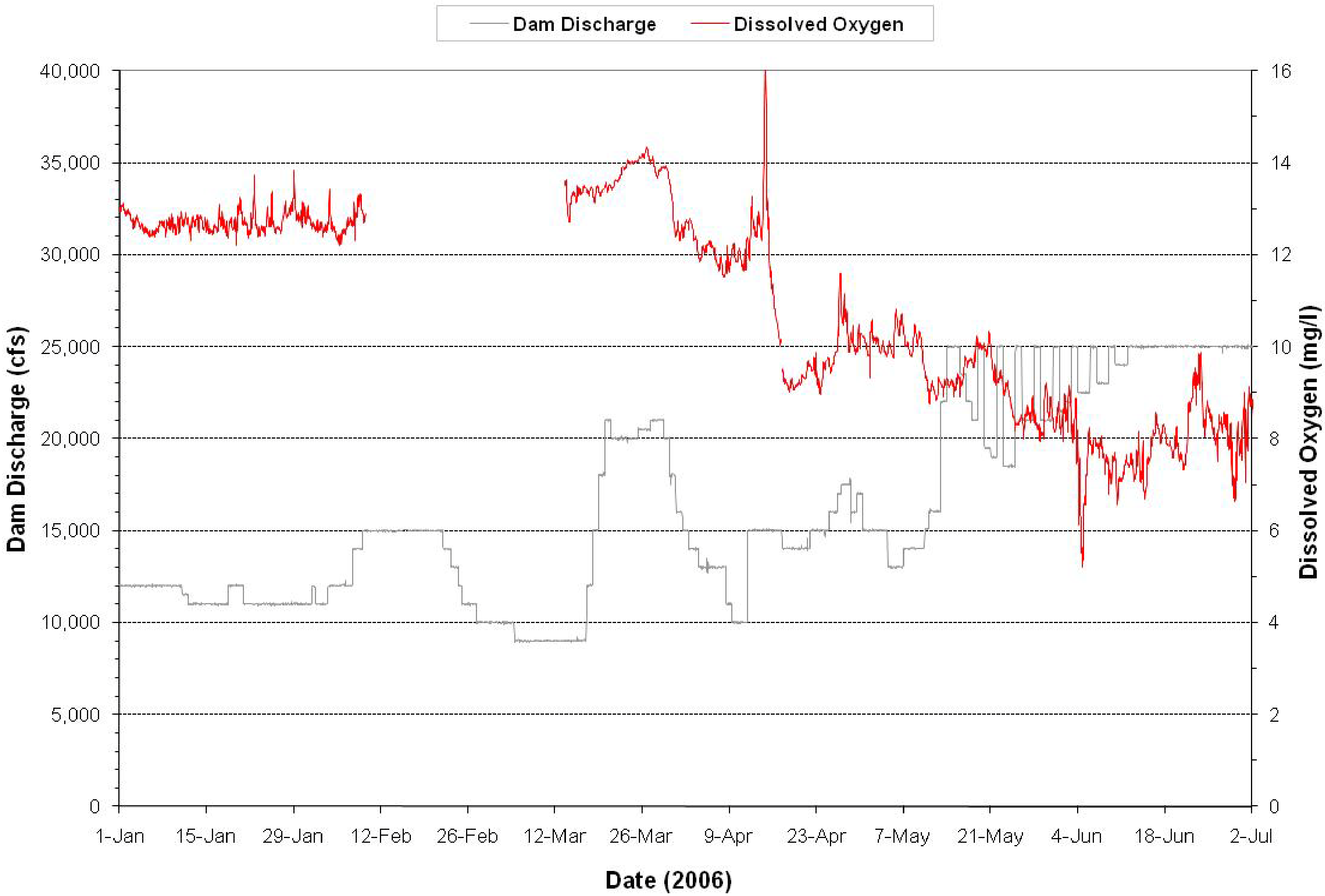

Plate 407. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the powerplant during the period January through June 2006.
Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

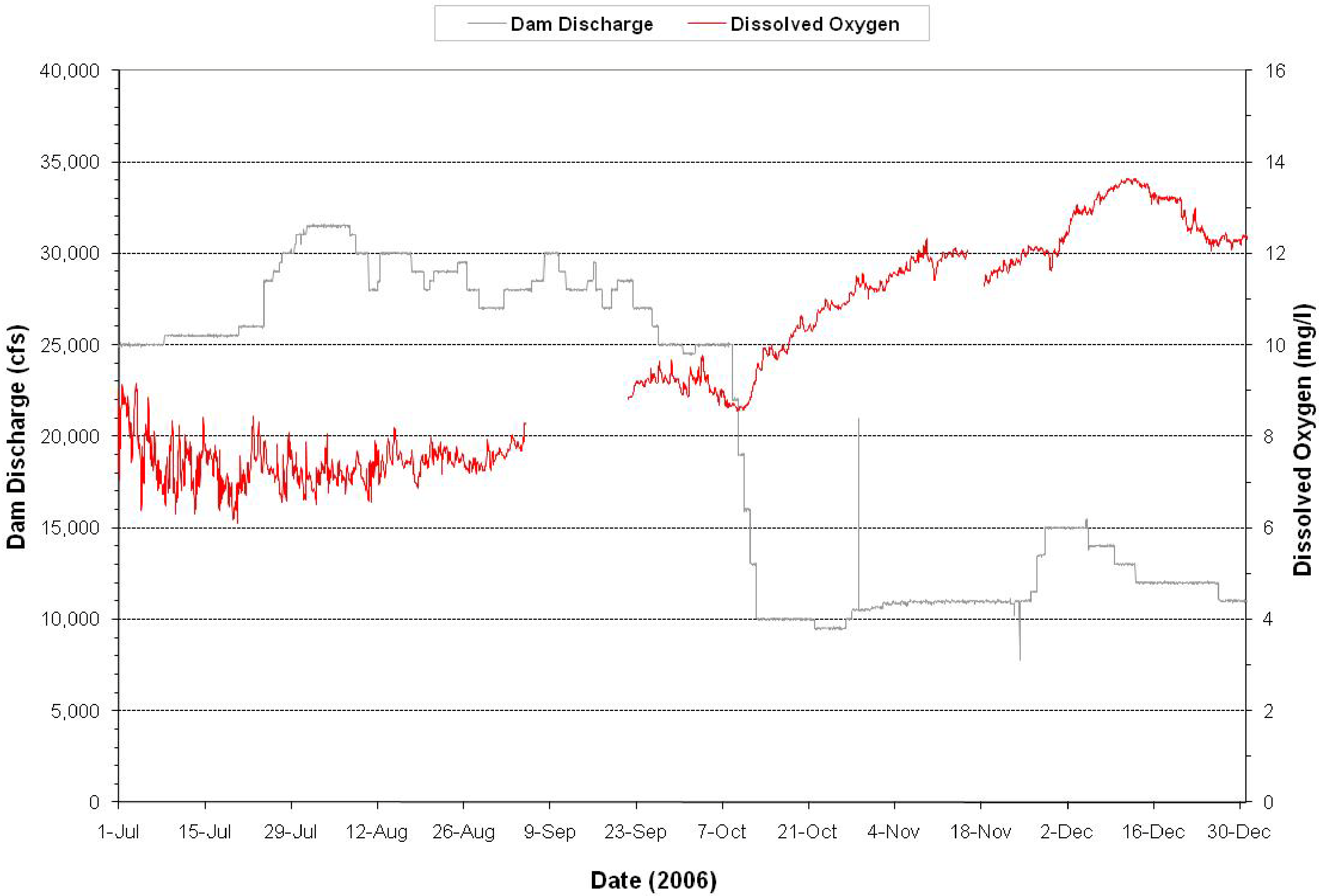

Plate 408. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the powerplant during the period July through December 2006.
Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

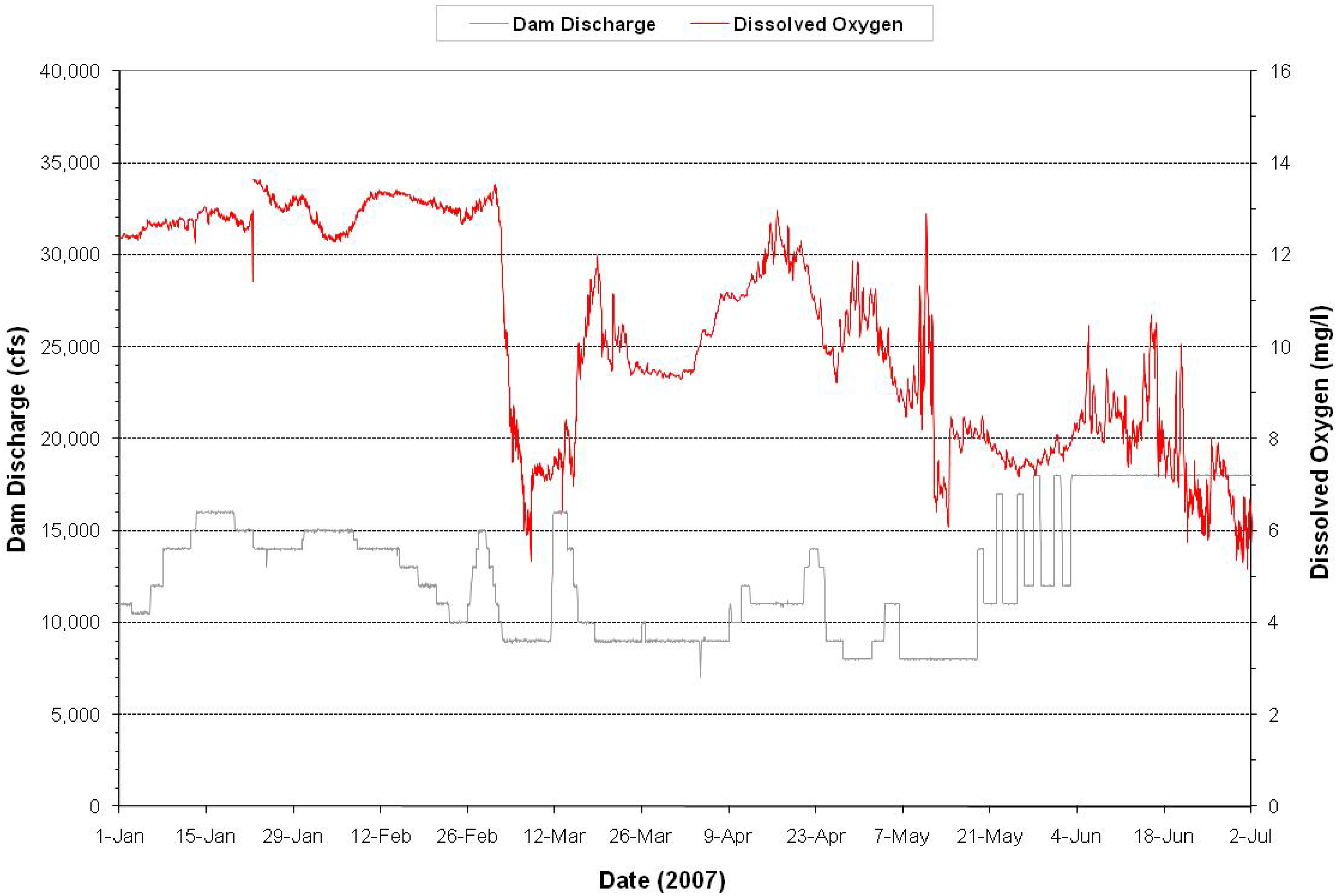

Plate 409. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the powerplant during the period January through June 2007.

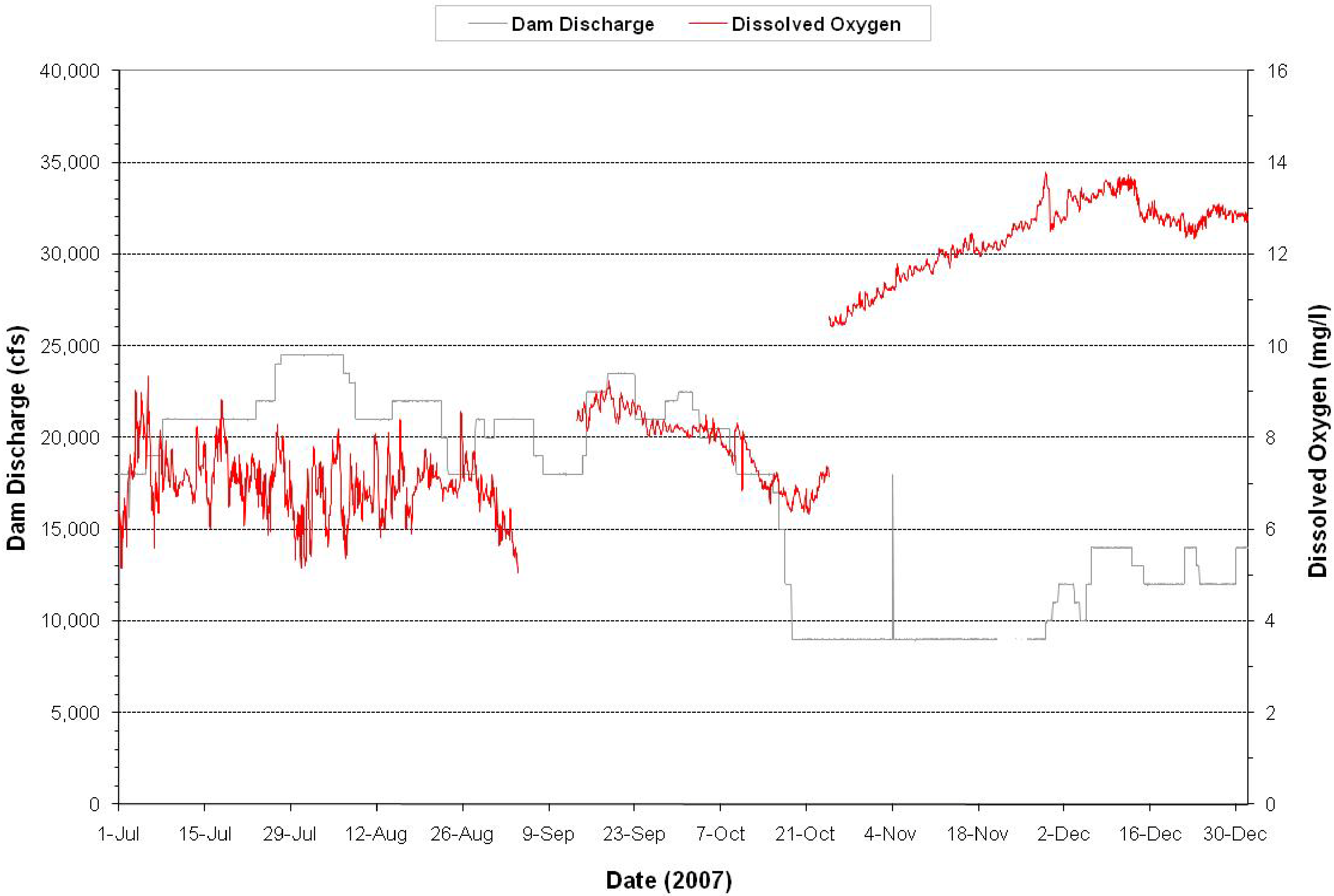

Plate 410. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the powerplant during the period July through December 2007.
Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

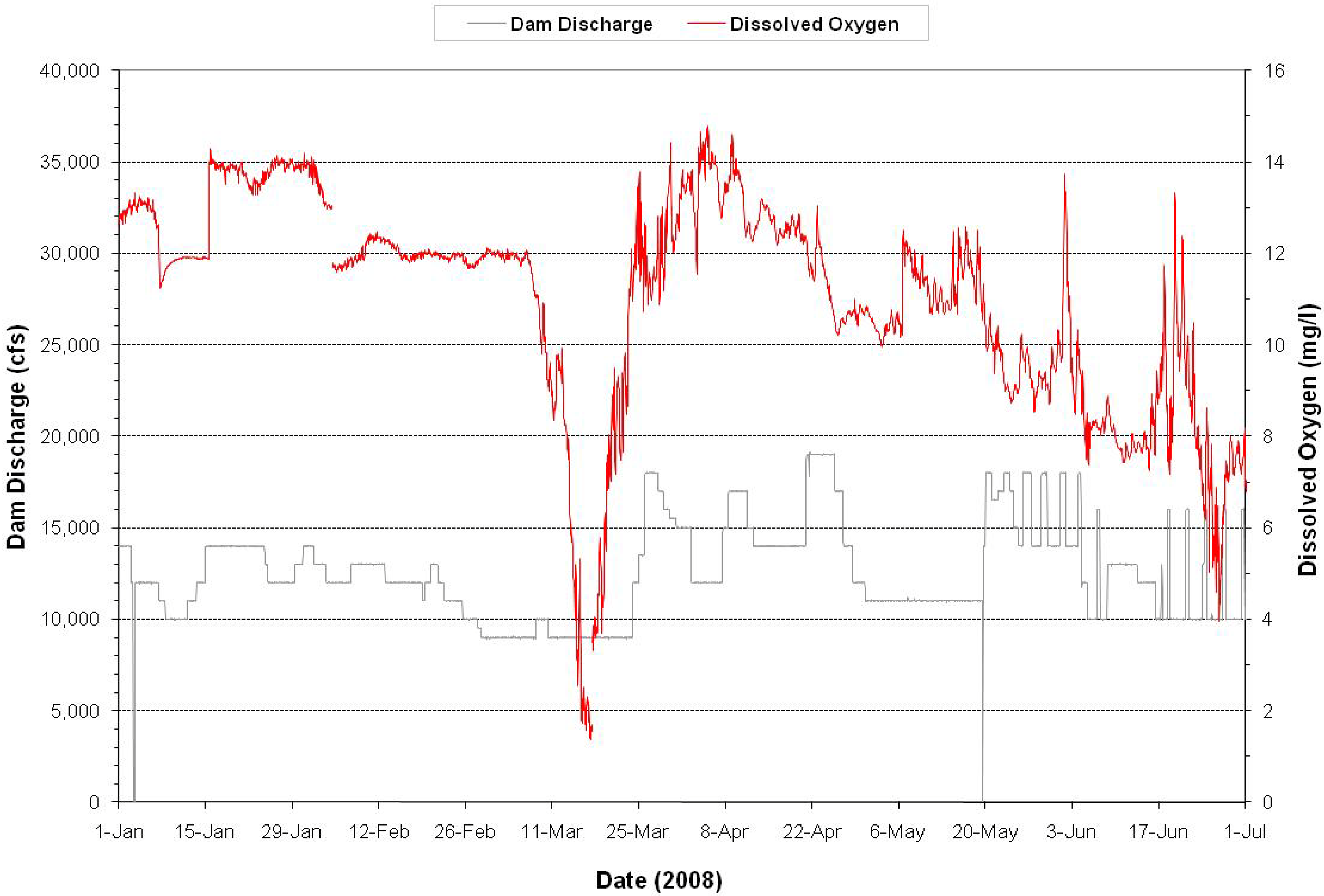

Plate 411. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the powerplant during the period January through June 2008.

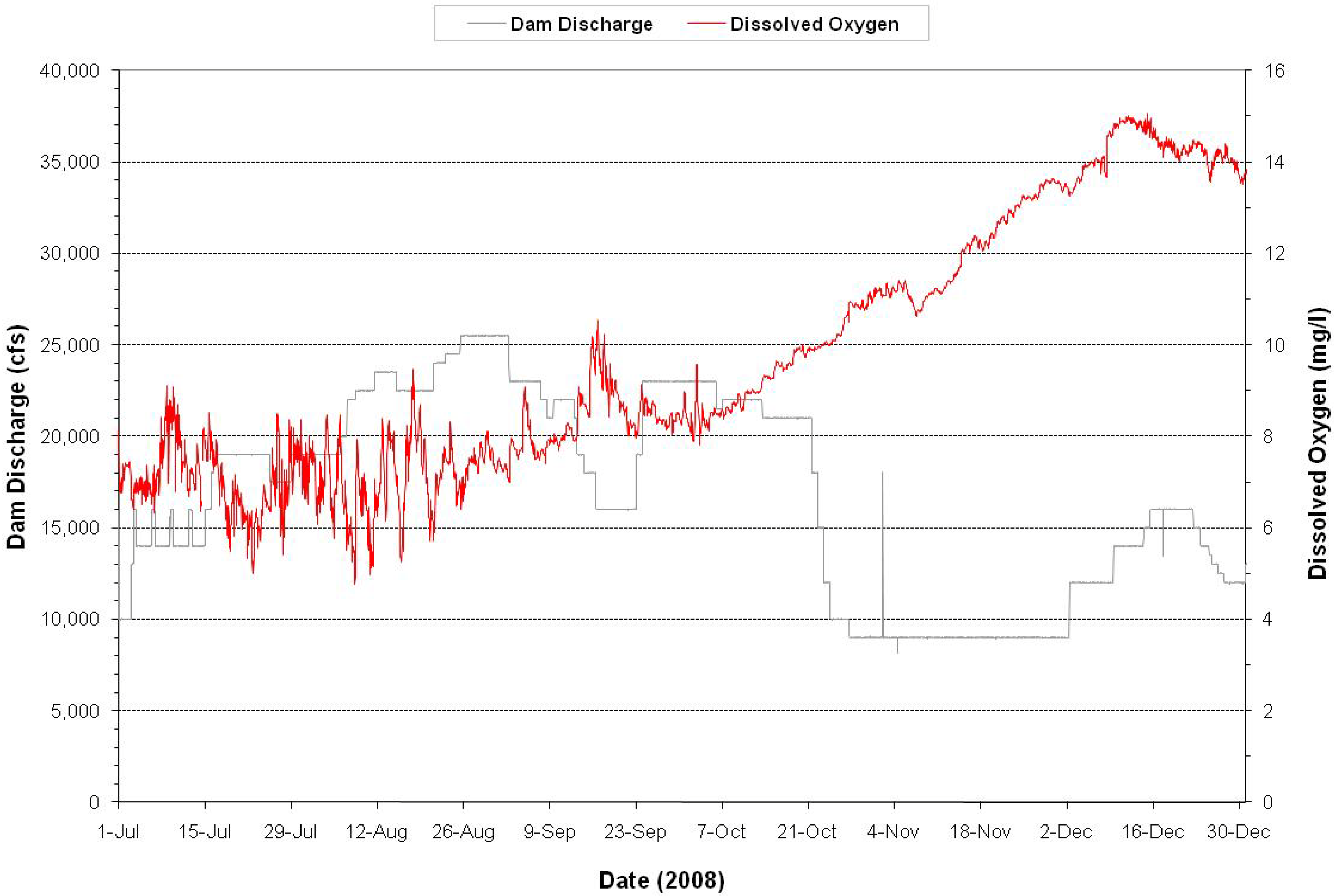

Plate 412. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the powerplant during the period July through December 2008.

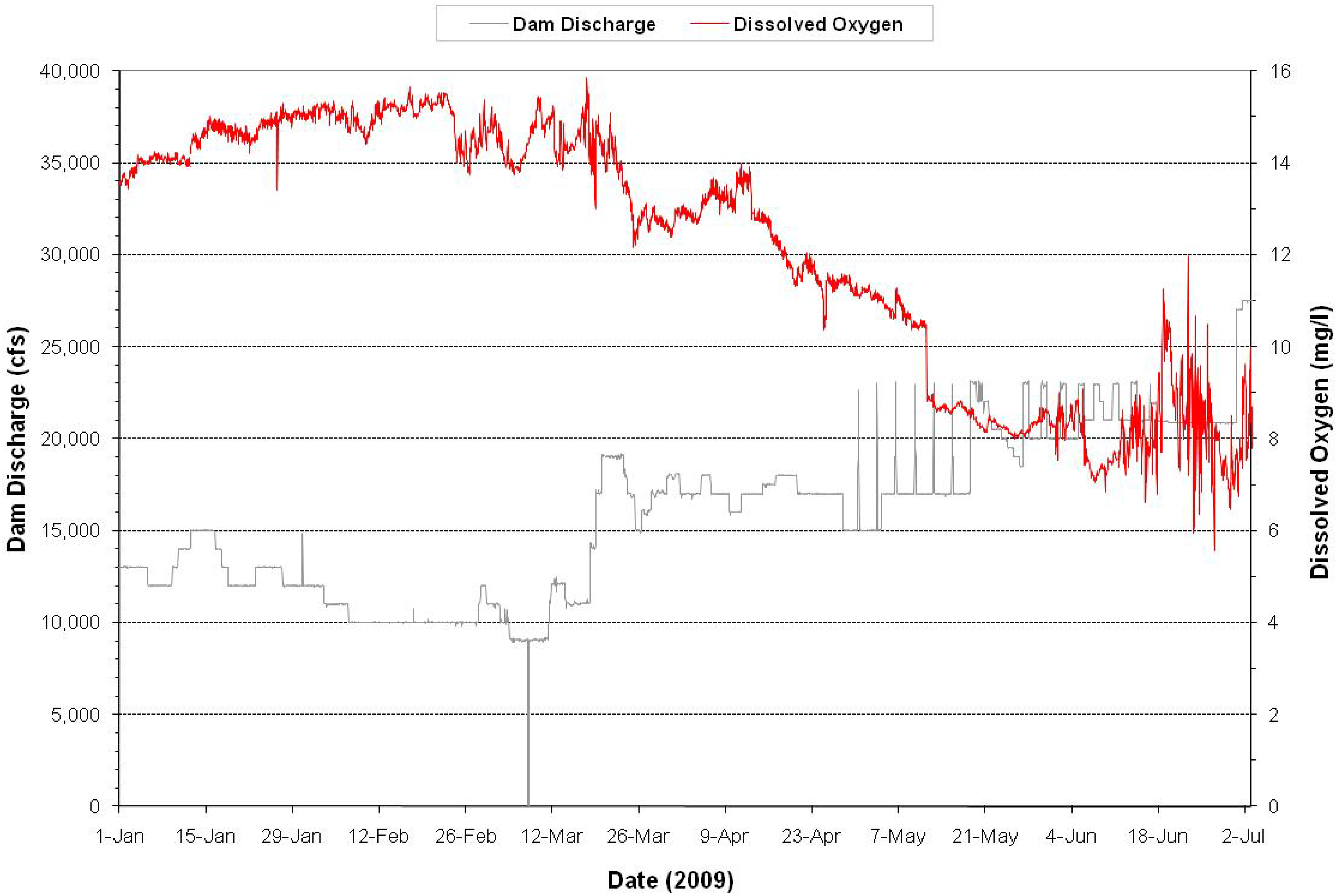

Plate 413. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the powerplant during the period January through June 2009.

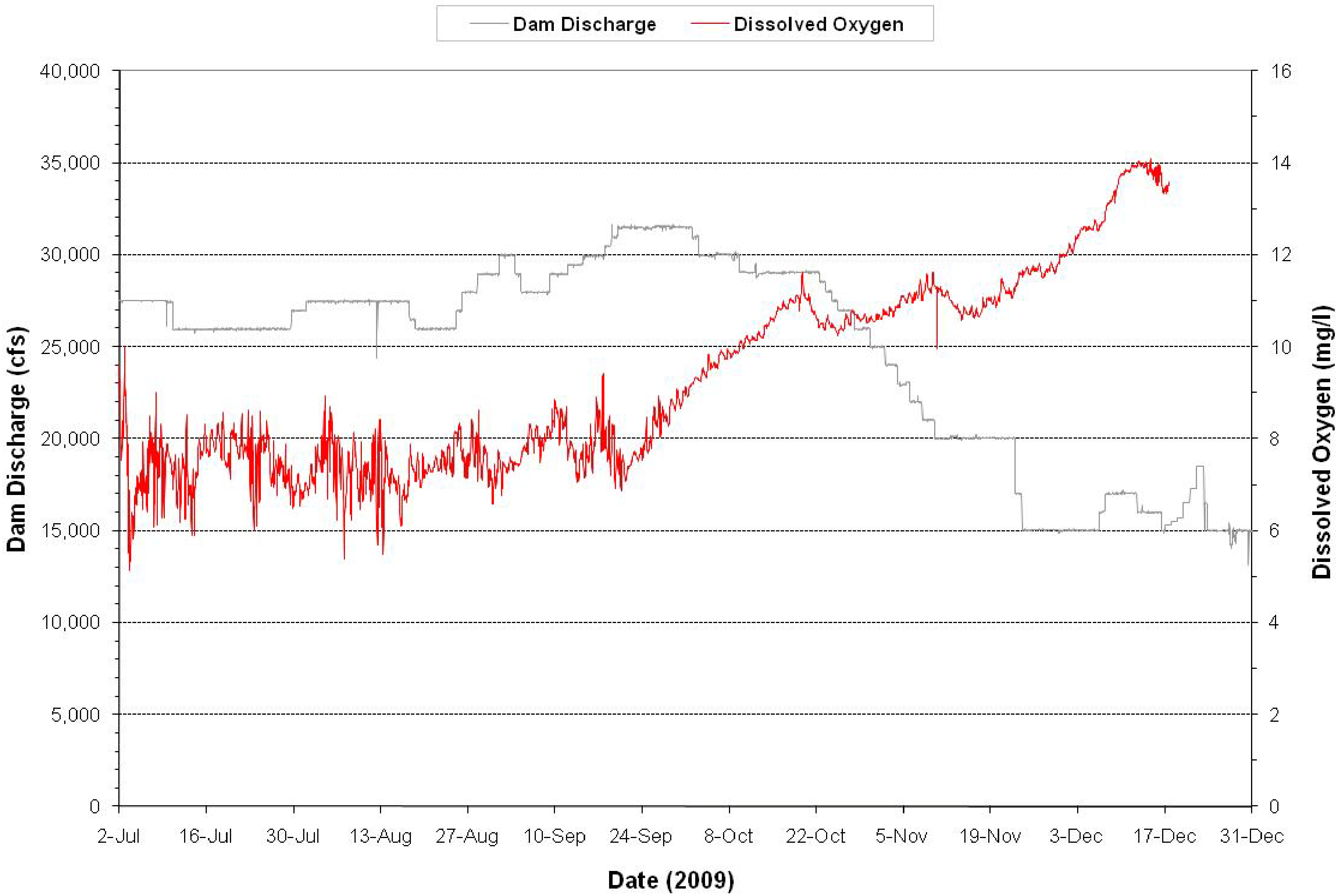

Plate 414. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the powerplant during the period July through December 2009.

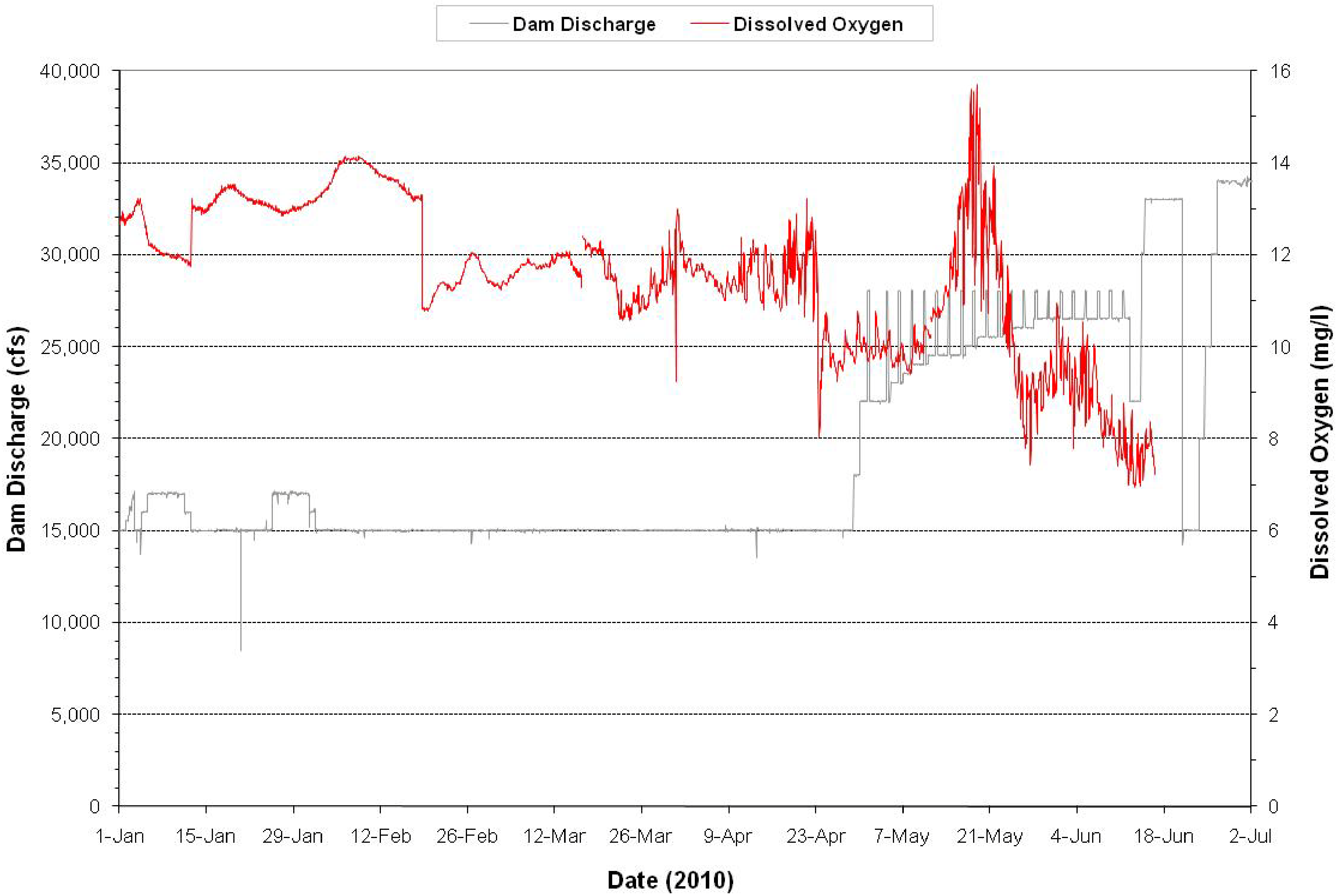

Plate 415. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the powerplant during the period January through June 2010.
Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

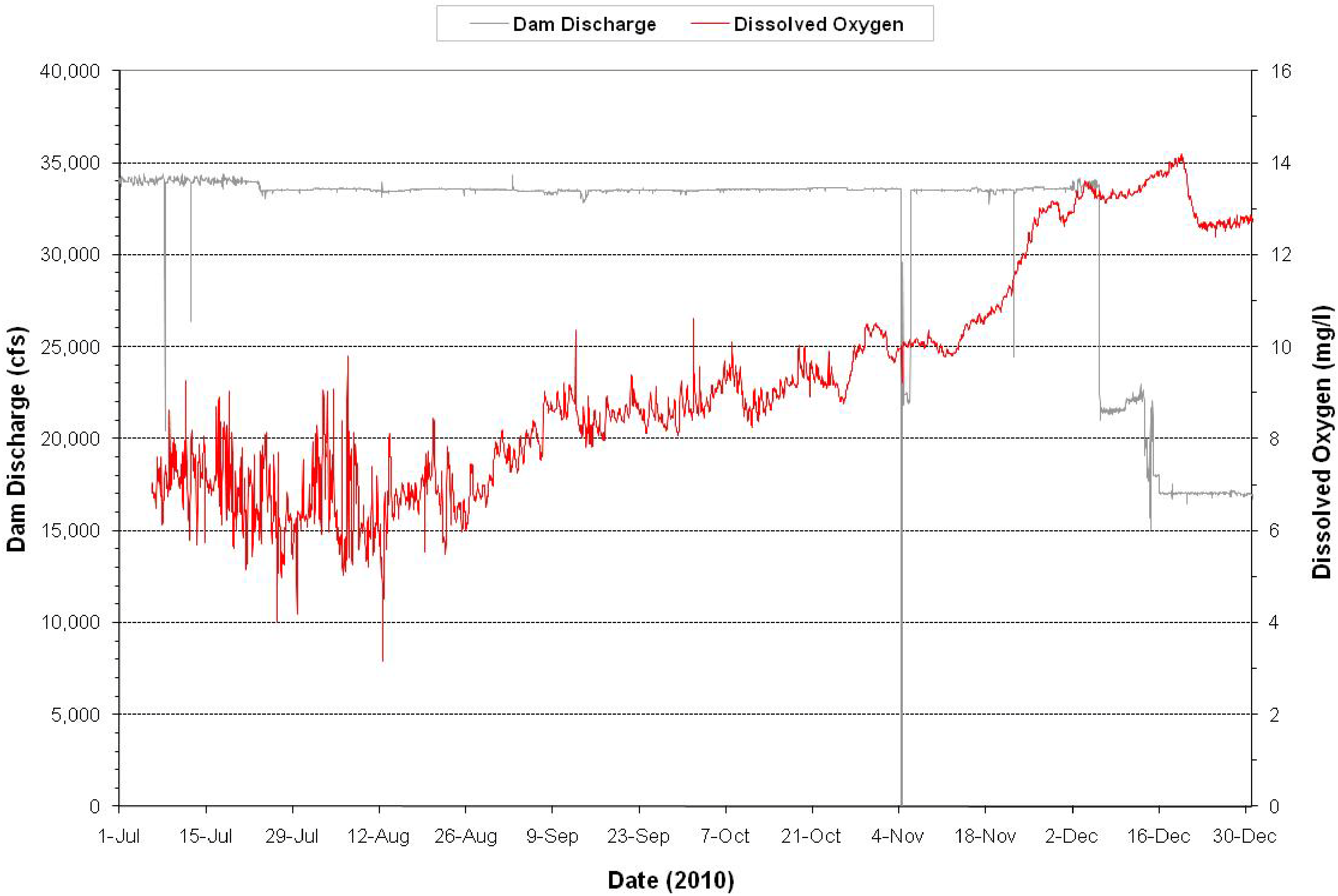

Plate 416. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the powerplant during the period July through December 2010.
Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

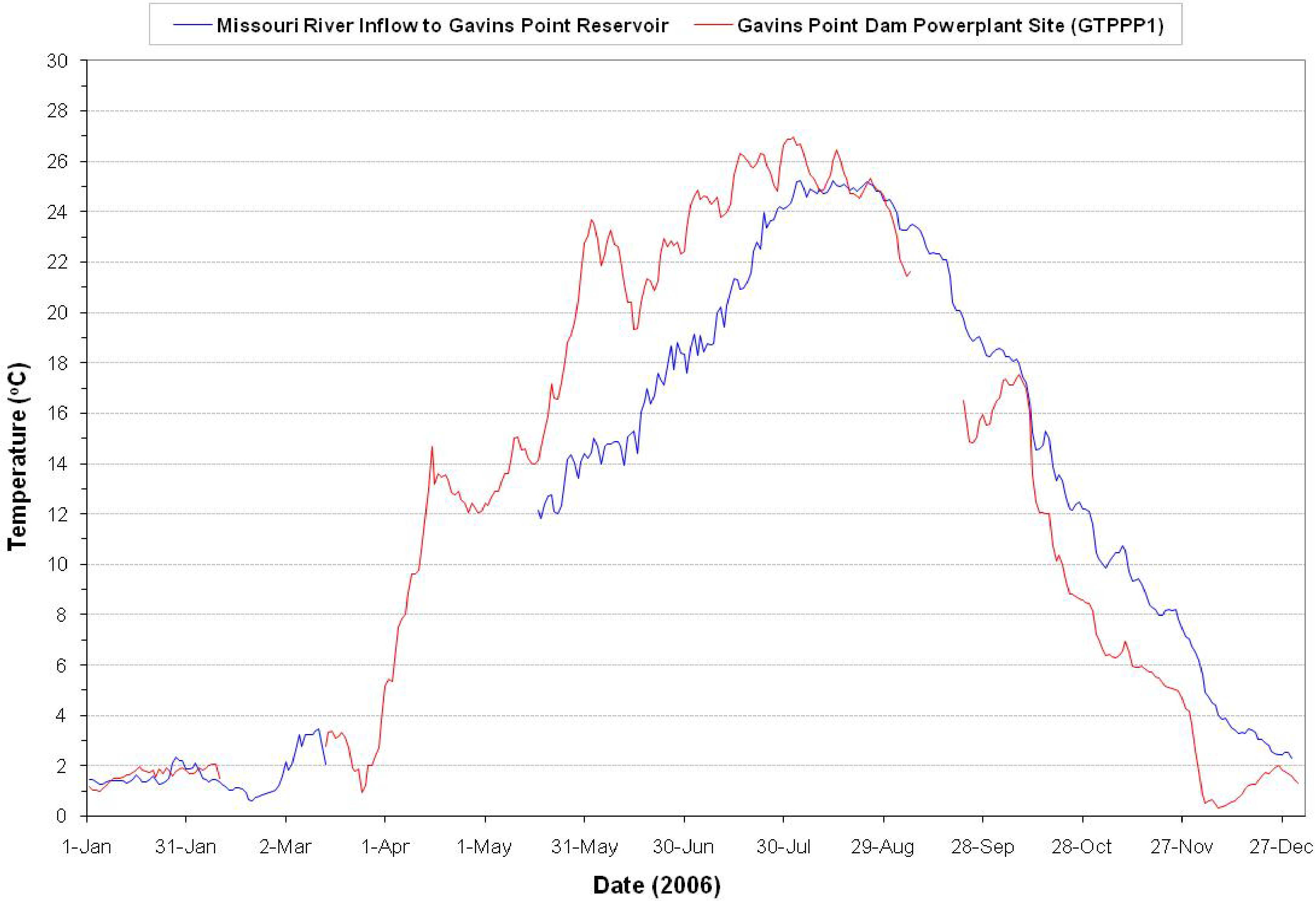

Plate 417. Mean daily water temperatures monitored at the Gavins Point Powerplant (i.e., site GTPPP1) and estimated for the Missouri River inflow to Lewis and Clark Lake during 2006.
Note: Gaps in temperature plots are periods when monitoring equipment was not operational.

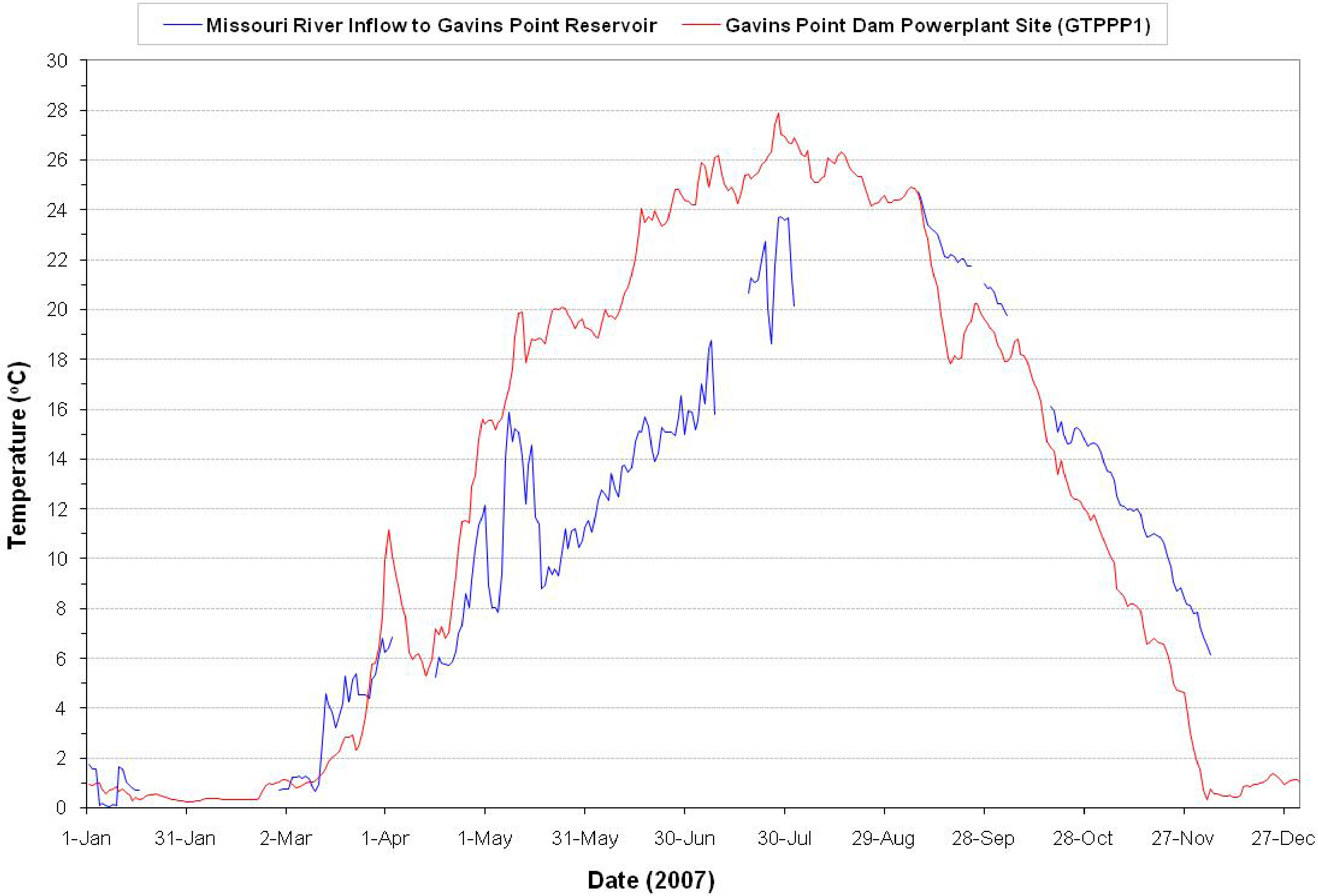

Plate 418. Mean daily water temperatures monitored at the Gavins Point Powerplant (i.e., site GTPPP1) and estimated for the Missouri River inflow to Lewis and Clark Lake during 2007.
Note: Gaps in temperature plots are periods when monitoring equipment was not operational.

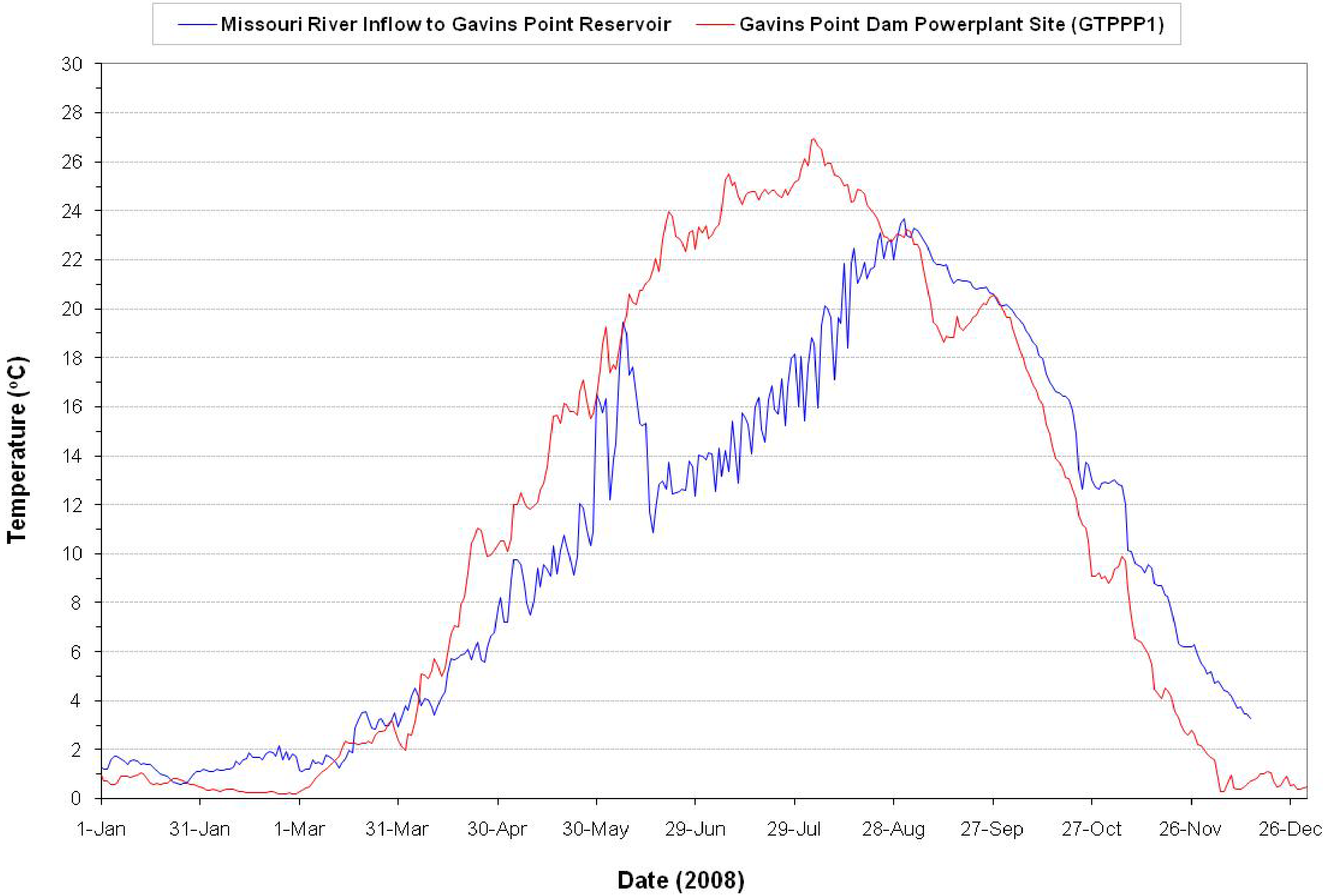

Plate 419. Mean daily water temperatures monitored at the Gavins Point Powerplant (i.e., site GTPPP1) and estimated for the Missouri River inflow to Lewis and Clark Lake during 2008.

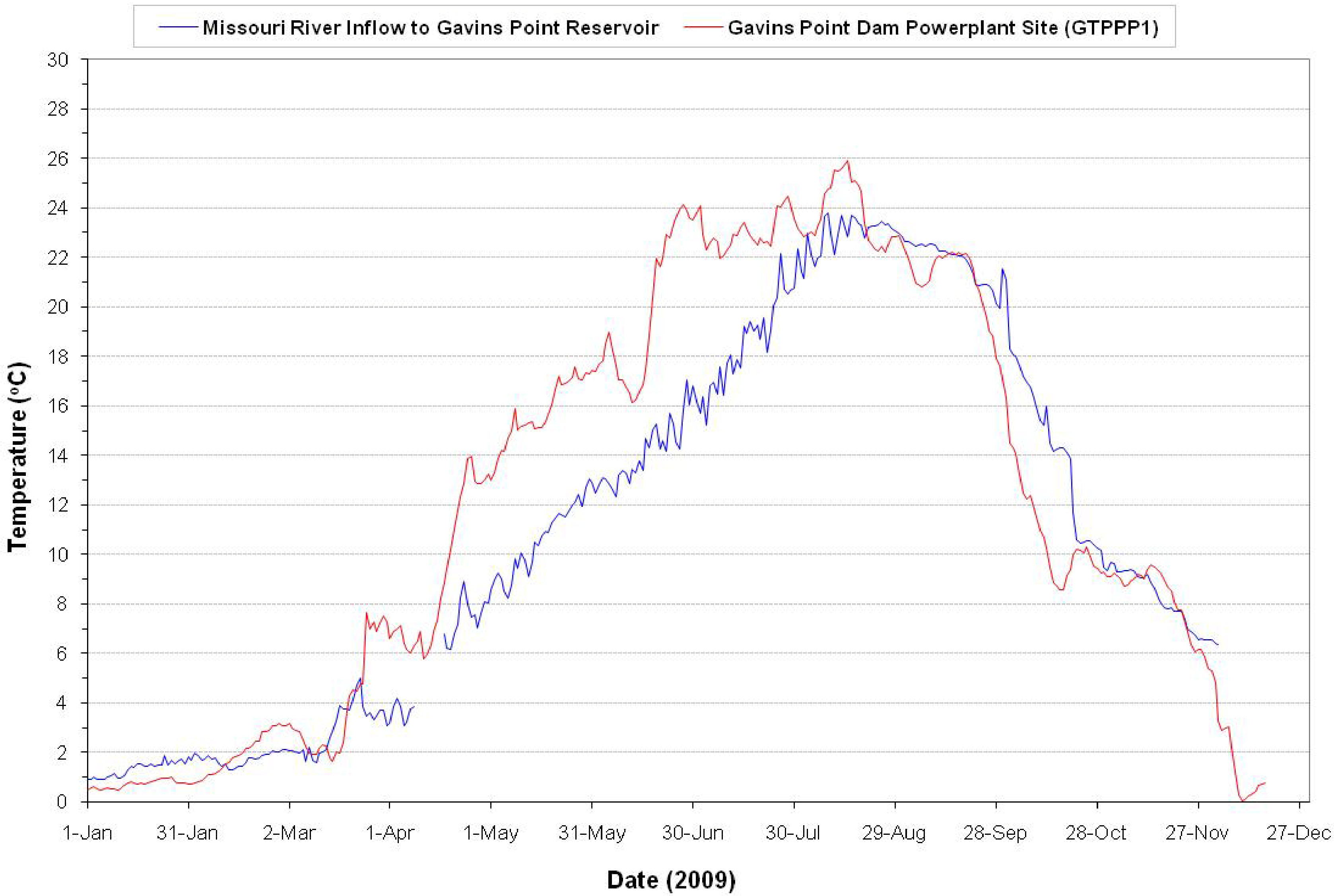

Plate 420. Mean daily water temperatures monitored at the Gavins Point Powerplant (i.e., site GTPPP1) and estimated for the Missouri River inflow to Lewis and Clark Lake during 2009.
Note: Gaps in temperature plots are periods when monitoring equipment was not operational.

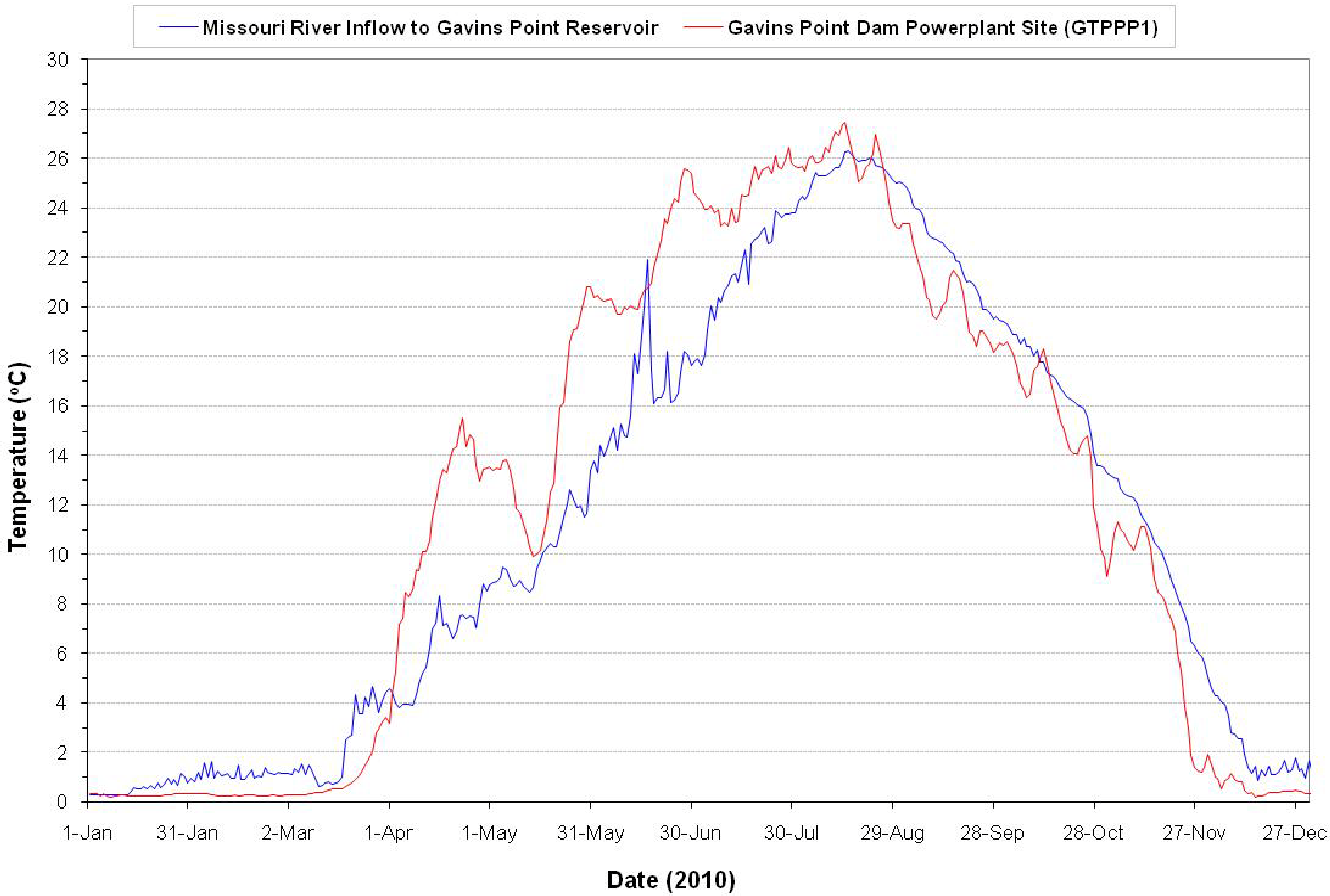

Plate 421. Mean daily water temperatures monitored at the Gavins Point Powerplant (i.e., site GTPPP1) and estimated for the Missouri River inflow to Lewis and Clark Lake during 2010.

Plate 422. Summary of near-surface water quality conditions monitored in the Missouri River at the Gavins Point Dam tailwaters (i.e., site GPTRRTW1) during the 5-year period 2006 through 2010.

	Monitoring Results						Water Quality Standards Attainment		
Parameter	**Detection Limit[A]**	**No. of Obs.**	**Mean[B]**	**Median**	**Min.**	**Max.**	**State WQS Criteria[C]**	**No. of WQS Exceedances**	**Percent WQS Exceedance**
Gavins Point Dam Discharge:									
Streamflow (cfs)	1	74	18,681	16,491	8,000	46,937	-----	-----	-----
Field Measurements:									
Water Temperature (°C)	0.1	72	13.1	12.9	0.0	27.1	27[1,2,6], 29[1,2,6]	1, 0	1%, 0%
Dissolved Oxygen (mg/l)	0.1	71	10.3	10.0	6.8	15.1	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	71	97.1	97.2	60.5	117.8	-----	-----	-----
Oxidation-Reduction Potential	1	39	361	368	150	472	-----	-----	-----
pH (S.U.)	0.1	70	8.3	8.3	7.6	8.8	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Specific Conductance (umhos/cm)	1	72	686	701	511	800	2,000[4]	0	0%
Turbidity (NTU)	1	71	22	14	n.d.	149	-----	-----	-----
Laboratory Results:									
Alkalinity, Total (mg/l)	7	73	158	157	130	190	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	71	3.6	3.3	2.3	7.5	-----	-----	-----
CBOD 5-day (mg/l)	2	6	2	3	n.d.	3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	73	11	11	n.d.	23	-----	-----	-----
Chloride (mg/l)	1	72	12	12	8	29	438[3,6], 250[3,8]	0	0%
Chlorophyll *a* (ug/l)	1	17	13	12	2	29	-----	-----	-----
Color (APHA)	1	21	7	7	n.d.	14	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	70	453	459	350	550	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	0	0%
Nitrogen, Ammonia Total	0.02	73	-----	0.04	n.d.	0.56	4.7 [1,6,9], 1.5 [1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	73	0.6	0.5	n.d.	1.8	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	72	-----	0.11	n.d.	0.60	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/l)	0.1	72	0.7	0.6	n.d.	2.3	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	15	-----	n.d.	N.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	73	0.05	0.04	n.d.	0.23	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	23	-----	n.d.	n.d.	0.30			
Sulfate (mg/l)	1	22	203	205	166	233	-----	-----	-----
Suspended Sediment, Total (mg/l)	4	7	20	16	7	5	-----	-----	-----
Suspended Solids, Total (mg/l)	4	73	10	9	n.d.	68	158[1,6], 90[1,8]	0	0%
THM Formation Potential, Total (mg/l)	4	15	229	191	152	356	-----	-----	-----

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Parameter	**Monitoring Results**						**Water Quality Standards Attainment**		
	Detection Limit[A]	**No. of Obs.**	**Mean**[B]	**Median**	**Min.**	**Max.**	**State WQS Criteria**[C]	**No. of WQS Exceedances**	**Percent WQS Exceedance**
Laboratory Results (Metals and Pesticides):									
Aluminum, Dissolved (mg/l)	25	12	-----	n.d.	n.d.	50	750[10], 87[11], 200[12]	0	0%
Antimony, Dissolved (ug/l)	0.5	12	-----	n.d.	n.d.	1	88[10], 30[11], 6[12]	0	0%
Arsenic, Dissolved (ug/l)	1	12	2	2	n.d.	3	340[10], 16.7[11], 10[12]	0	0%
Barium, Dissolved (ug/l)	5	12	50	49	33	65	2,000[11]	0	0%
Beryllium, Dissolved (ug/l)	2	12	-----	n.d.	n.d.	n.d.	130[10], 5.3[11], 4[12]	0	0%
Cadmium, Dissolved (ug/l)	0.5	11	-----	n.d.	n.d.	n.d.	4.4[10], 0.43[11], 5[12]	0	0%
Calcium, Dissolved (mg/l)	0.01	17	56	56	48	62	-----	-----	-----
Chromium, Dissolved (ug/l)	10	17	-----	n.d.	n.d.	n.d.	1,103[10], 143[11], 100[12]	0	0%
Copper, Dissolved (ug/l)	2	16	-----	n.d.	n.d.	n.d.	29[10], 18[11], 1,000[12]	0	0%
Hardness, Total (mg/l)	0.4	15	222	224	179	240	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	12	-----	n.d.	n.d.	n.d.	154[10], 6.0[11], 15[12]	0	0%
Magnesium, Dissolved (mg/l)	0.01	13	20	20	15	23	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	17	-----	n.d.	n.d.	n.d.	1.4[10]	0	0%
Mercury, Total (ug/l)	0.05	17	-----	n.d.	n.d.	n.d.	0.77[11], 2[12]	0	0%
Nickel, Dissolved (ug/l)	10	17	-----	n.d.	n.d.	n.d.	926[10], 103[11], 100[12]	0	0%
Selenium, Total (ug/l)	1	12	3	3	n.d.	5	20[4,10], 5[11], 50[12]	0	0%
Silver, Dissolved (ug/l)	1	17	-----	n.d.	n.d.	n.d.	13[10], 100[12]	0	0%
Sodium, Dissolved (mg/l)	0.01	5	61	63	53	67	-----	-----	-----
Thallium, Dissolved (ug/l)	0.5	12	-----	n.d.	n.d.	n.d.	1,400[10], 6.3[11], 2[12]	0	0%
Zinc, Dissolved (ug/l)	10	17	-----	n.d.	n.d.	11	232[10,11], 5,000[12]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	31	-----	n.d.	n.d.	0.40	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	30	-----	n.d.	n.d.	n.d.	760[10], 76[11], 2[12]	0	0%
Atrazine, Total (ug/l)[D]	0.05	61	-----	n.d.	n.d.	0.50	330[10], 12[11], 3[3]	0	0%
Metolachlor, Total (ug/l)[D]	0.05	61	-----	n.d.	n.d.	0.10	390[10], 100[11]	0	0%
Pesticide Scan (ug/l)[E]	0.05						-----	-----	-----
Atrazine, Total (ug/l)		11	-----	n.d.	n.d.	0.20	330[10], 12[11], 3[3]	0	0%

n.d. = Not detected.

[A] Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- [2] South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- [3] Criteria for the protection of domestic water supply waters.
- [4] Criteria for the protection of agricultural water supply waters.
- [5] Criteria for the protection of commerce and industry waters.
- [6] Daily maximum criterion (monitoring results directly comparable to criterion).
- [7] Daily minimum criterion (monitoring results directly comparable to criterion).
- [8] 30-day average criterion (monitoring results not directly comparable to criterion).
- [9] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- [10] Acute (CMC) criterion for the protection of freshwater aquatic life.
- [11] Chronic (CCC) criterion for the protection of freshwater aquatic life.
- [12] Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] Immunoassay analysis.

[E] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan. Individual pesticides were not detected unless listed under pesticide scan.

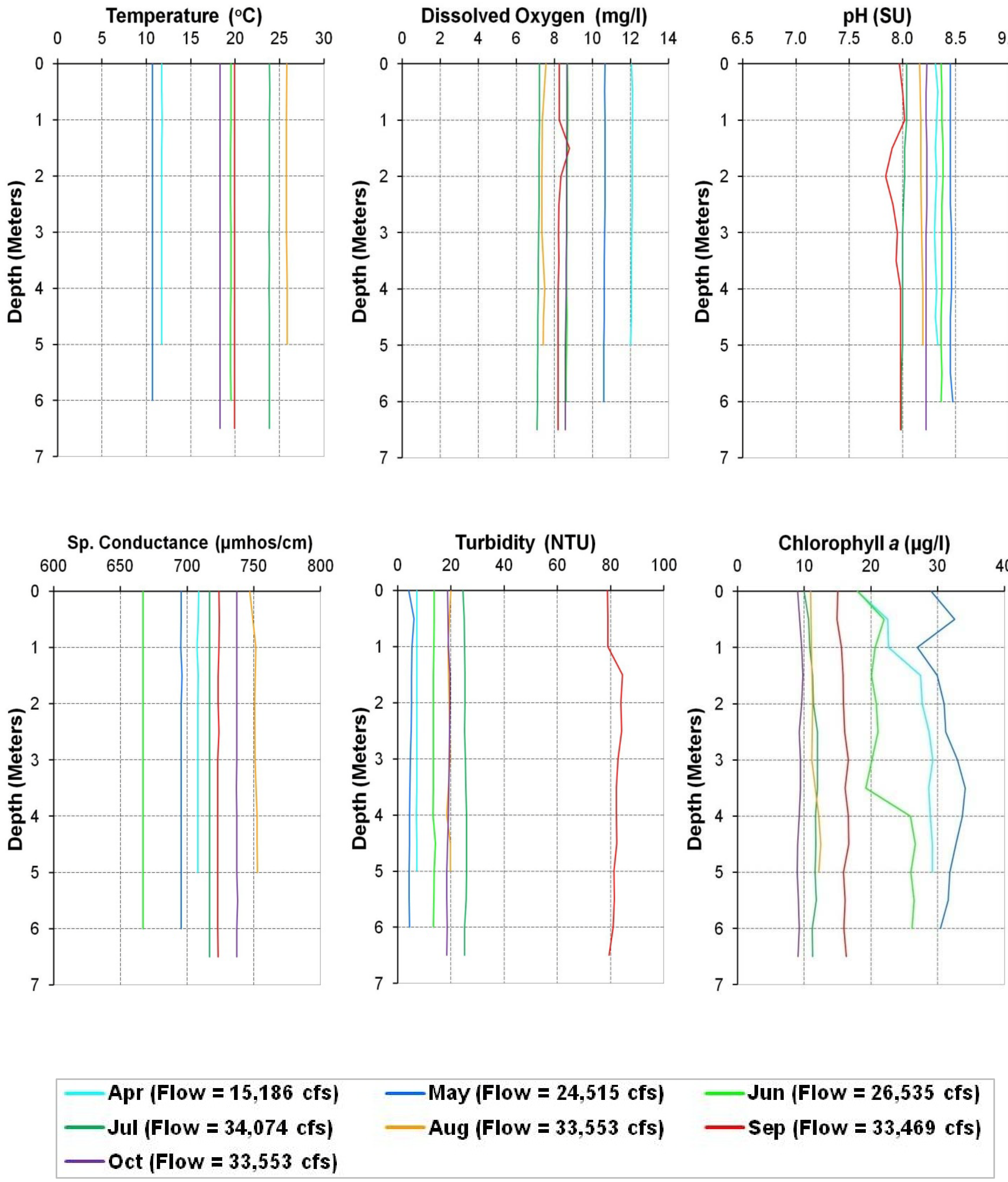

Plate 423. Water temperature, dissolved oxygen, pH, specific conductance, turbidity, and chlorophyll *a* depth profiles for the Missouri River compiled from data collected at the Gavins Point Dam tailwaters site (i.e., GPTPRRTW1) during 2010.

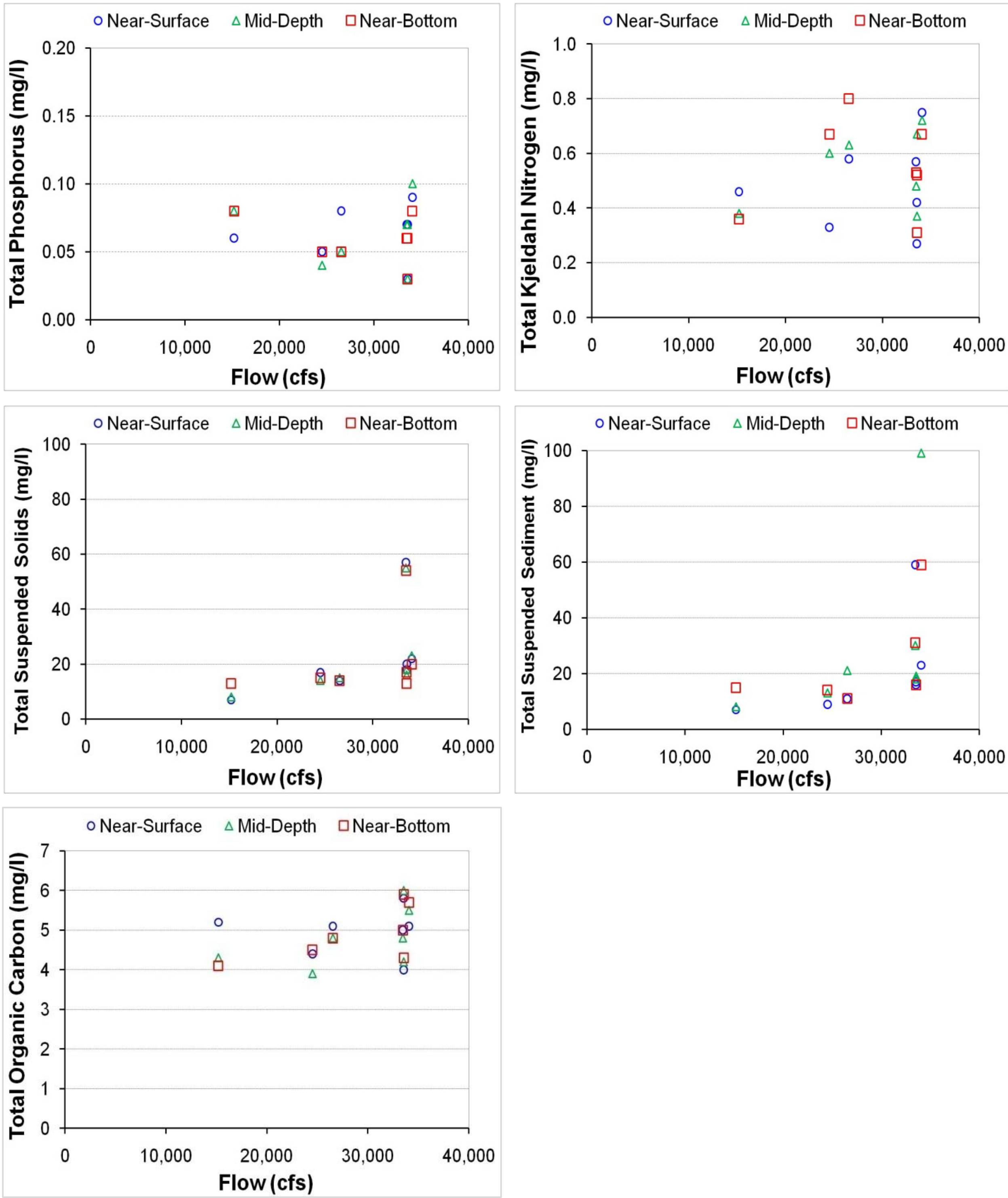

Plate 424. Comparison of flow and measured near-surface, mid-depth, and near-bottom concentrations of total phosphorus, total Kjeldahl nitrogen, total suspended solids, total suspended sediment, and total organic carbon in the Missouri River at the Gavins Point Dam tailwaters (i.e., site GPTRRTW1) during 2010.

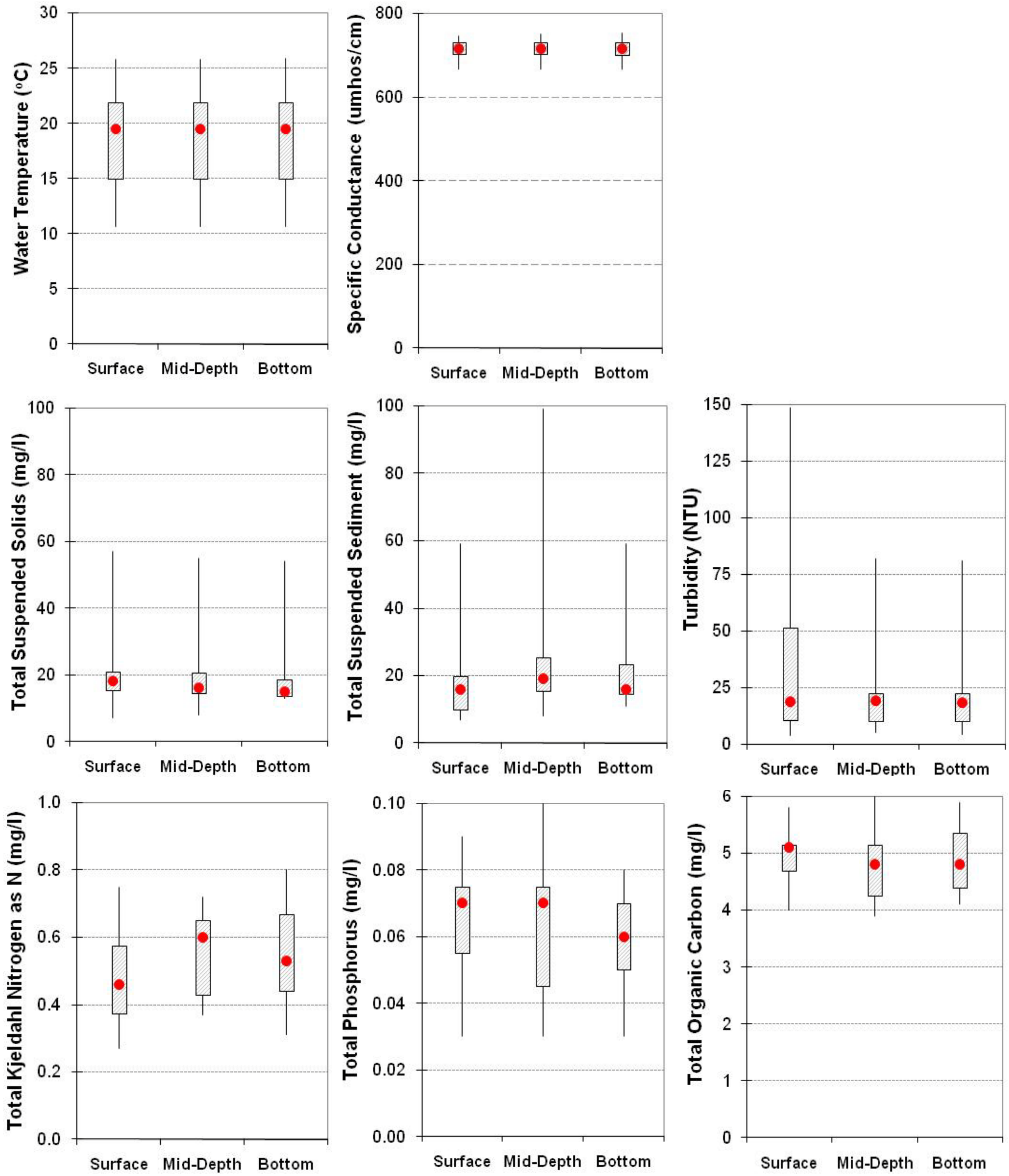

Plate 425. Box plots comparing paired surface, mid-depth, and bottom water temperature, specific conductance, total suspended solids, total suspended sediment, turbidity, total Kjeldahl nitrogen, total phosphorus, and total organic carbon measurements taken in the Missouri River at site GPTRRTW1 during 2010. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 426. Summary of near-surface water quality conditions monitored in the Missouri River near Maskell, Nebraska (i.e., site MORRR0774) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Estimated Discharge:									
Streamflow (cfs)	1	56	23,003	23,205	9,337	45,977	-----	-----	-----
Field Measurements:									
Water Temperature (°C)	0.1	59	16.1	18.3	0.1	29.1	27(1,2,6), 29(1,2,6)	2, 1	3%, 2%
Dissolved Oxygen (mg/l)	0.1	58	10	9.4	7.5	14.2	5(1,7)	0	0%
Dissolved Oxygen (% Sat.)	0.1	58	102.1	102.4	68.7	121.0	-----	-----	-----
Oxidation-Reduction Potential	1	30	345	348	118	481	-----	-----	-----
pH (S.U.)	0.1	57	8.3	8.4	7.7	8.6	6.5(1,3,7), 9.0(1,3,6), 9.5(5,6)	0	0%
Specific Conductance (umhos/cm)	1	59	704	711	597	780	2,000(4)	0	0%
Turbidity (NTU)	1	58	34	25	3	215	-----	-----	-----
Laboratory Results:									
Alkalinity, Total (mg/l)	7	60	162	160	140	205	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	58	308	3.4	1.7	8.1	-----	-----	-----
CBOD 5-day (mg/l)	2	6	2	2	n.d.	3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	60	14	13	n.d.	27	-----	-----	-----
Chloride (mg/l)	1	60	12	12	7	31	438(3,6), 250(3,8)	0	0%
Color (APHA)	1	15	9	8	4	20	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	58	473	470	416	554	1,750(3,6), 1,000(3,8), 3,500(5,6), 2,000(5,8)	0	0%
Nitrogen, Ammonia Total	0.02	60	-----	0.03	n.d.	0.54	3.9(1,6,9), 0.95(1,8,9)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	60	0.7	0.6	n.d.	2.0	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	60	0.20	0.19	n.d.	0.70	10(3,6), 100(4,6)	0	0%
Nitrogen, Total (mg/l)	0.1	60	0.6	0.7	0.2	2.4	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	11	-----	0.03	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	60	0.09	0.07	n.d.	0.40	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	19	-----	n.d.	n.d.	0.05	-----	-----	-----
Sulfate (mg/l)	1	18	208	212	178	226	-----	-----	-----
Suspended Solids, Total (mg/l)	4	60	37	24	n.d.	179	158(1,6), 90(1,8)	0	0%

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Parameter	**Monitoring Results**						**Water Quality Standards Attainment**		
	Detection Limit(A)	**No. of Obs.**	**Mean**(B)	**Median**	**Min.**	**Max.**	**State WQS Criteria**(C)	**No. of WQS Exceedances**	**Percent WQS Exceedance**
Laboratory Results (Metals and Pesticides):									
Aluminum, Dissolved (mg/l)	25	12	-----	n.d.	n.d.	60	750(10), 87(11), 200(12)	0	0%
Antimony, Dissolved (ug/l)	0.5	12	-----	n.d.	n.d.	1	88(10), 30(11), 6(12)	0	0%
Arsenic, Dissolved (ug/l)	1	12	2	2	1	3	340(10), 16.7(11), 10(12)	0	0%
Barium, Dissolved (ug/l)	5	12	56	55	46	73	2,000(11)	0	0%
Beryllium, Dissolved (ug/l)	2	12	-----	n.d.	n.d.	n.d.	130(10), 5.3(11), 4(12)	0	0%
Cadmium, Dissolved (ug/l)	0.5	16	-----	n.d.	n.d.	n.d.	4.6(10), 0.44(11), 5(12)	0	0%
Calcium, Dissolved (mg/l)	0.01	16	60	60	55	70	-----	-----	-----
Chromium, Dissolved (ug/l)	10	16	-----	n.d.	n.d.	n.d.	1,143(10), 149(11), 100(12)	0	0%
Copper, Dissolved (ug/l)	2	15	-----	n.d.	n.d.	2	30(10), 19(11), 1,000(12)	0	0%
Hardness, Total (mg/l)	0.4	15	241	234	212	342	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	12	-----	n.d.	n.d.	n.d.	161(10), 6.3(11), 15(12)	0	0%
Magnesium, Dissolved (mg/l)	0.01	14	22	21	18	29	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	16	-----	n.d.	n.d.	n.d.	1.4(10)	0	0%
Mercury, Total (ug/l)	0.05	16	-----	n.d.	n.d.	n.d.	0.77(11), 2(12)	0	0%
Nickel, Dissolved (ug/l)	10	16	-----	n.d.	n.d.	n.d.	961(10), 107(11), 100(12)	0	0%
Selenium, Total (ug/l)	1	12	3	3	n.d.	4	20(4,10), 5(11), 50(12)	0	0%
Silver, Dissolved (ug/l)	1	16	-----	n.d.	n.d.	n.d.	15(10), 100(12)	0	0%
Sodium, Dissolved (mg/l)	0.01	5	63	66	54	67	-----	-----	-----
Thallium, Dissolved (ug/l)	0.5	12	-----	n.d.	n.d.	n.d.	1,400(10), 6.3(11), 2(12)	0	0%
Zinc, Dissolved (ug/l)	10	16	-----	n.d.	n.d.	97	241(10,11), 5,000(12)	0	0%
Acetochlor, Total (ug/l)(D)	0.05	12	-----	n.d.	n.d.	0.50	-----	-----	-----
Alachlor, Total (ug/l)(D)	0.05	28	-----	n.d.	n.d.	0.10	760(10), 76(11), 2(12)	0	0%
Atrazine, Total (ug/l)(D)	0.05	51	-----	n.d.	n.d.	3.70	330(10), 12(11), 3(3)	0, 0, 1	0%, 0%, 2%
Metolachlor, Total (ug/l)(D)	0.05	51	-----	n.d.	n.d.	0.50	390(10), 100(11)	0	0%
Pesticide Scan (ug/l)(E)	0.05								
Acetochlor, Total (ug/l)		10	-----	n.d.	n.d.	0.30	-----	-----	-----
Atrazine, Total (ug/l)		10	-----	n.d.	n.d.	0.20	330(10), 12(11), 3(3)	0	0%

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (11) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (12) Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan. Individual pesticides were not detected unless listed under pesticide scan.

Plate 427. Summary of near-surface water quality conditions monitored in the Missouri River at near Ponca, Nebraska (i.e., site MORRR0753) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Estimated Discharge:									
Streamflow (cfs)	1	57	23,556	23,369	9,452	54,168	-----	-----	-----
Field Measurements:									
Water Temperature (°C)	0.1	59	16.2	18.1	0.3	30.6	27(1,2,6), 29(1,2,6)	3, 2	5%, 3%
Dissolved Oxygen (mg/l)	0.1	58	9.8	9.4	7.3	14.3	5(1,7)	0	0%
Dissolved Oxygen (% Sat.)	0.1	58	100.6	100.6	60.8	125.2	-----	-----	-----
Oxidation-Reduction Potential	1	31	346	353	121	477	-----	-----	-----
pH (S.U.)	0.1	57	8.3	8.4	7.7	8.7	6.5(1,3,7), 9.0(1,3,6), 9.5(5,6)	0	0%
Specific Conductance (umhos/cm)	1	59	724	731	469	894	2,000(4)	0	0%
Turbidity (NTU)	1	58	41	27	4	246	-----	-----	-----
Laboratory Results:									
Alkalinity, Total (mg/l)	7	60	162	162	127	190	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	58	4.3	4.0	2.4	8.9	-----	-----	-----
CBOD 5-day (mg/l)	2	6	-----	n.d.	n.d.	3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	60	14	12	n.d.	45	-----	-----	-----
Chloride (mg/l)	1	60	13	13	7	26	438(3,6), 250(3,8)	0	0%
Chlorophyll *a* (ug/l)	1	7	20	18	8	34	-----	-----	-----
Color (APHA)	1	15	11	8	5	28	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	58	502	498	316	662	1,750(3,6), 1,000(3,8), 3,500(5,6), 2,000(5,8)	0	0%
Nitrogen, Ammonia Total	0.02	60	-----	0.03	n.d.	0.37	3.9 (1,6,9), 0.96 (1,8,9)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	60	0.8	0.6	0.2	4.3	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	60	-----	0.11	n.d.	1.10	10(3,6), 100(4,6)	0	0%
Nitrogen, Total (mg/l)	0.1	60	1.0	0.8	0.2	5.2	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	10	-----	0.04	n.d.	0.11	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	60	0.12	0.08	n.d.	0.60	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	19	-----	0.02	n.d.	0.09	-----	-----	-----
Sulfate (mg/l)	1	18	217	220	185	247	-----	-----	-----
Suspended Sediment, Total (mg/l)	4	7	57	52	37	87	-----	-----	-----
Suspended Solids, Total (mg/l)	4	60	47	32	n.d.	352	158(1,6), 90(1,8)	0	0%

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Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[(A)]	**No. of Obs.**	**Mean**[(B)]	**Median**	**Min.**	**Max.**	**State WQS Criteria**[(C)]	**No. of WQS Exceedances**	**Percent WQS Exceedance**
Laboratory Results (Metals and Pesticides):									
Aluminum, Dissolved (mg/l)	25	8	-----	n.d.	n.d.	690	750[(10)], 87[(11)], 200[(12)]	0, 1, 1	0%, 13%, 13%
Antimony, Dissolved (ug/l)	0.5	9	-----	n.d.	n.d.	0.7	88[(10)], 30[(11)], 6[(12)]	0	0%
Arsenic, Dissolved (ug/l)	1	9	3	3	2	3	340[(10)], 16.7[(11)], 10[(12)]	0	0%
Barium, Dissolved (ug/l)	5	9	57	57	48	66	2,000[(11)]	0	0%
Beryllium, Dissolved (ug/l)	2	9	-----	n.d.	n.d.	n.d.	130[(10)], 5.3[(11)], 4[(12)]	0	0%
Cadmium, Dissolved (ug/l)	0.5	13	-----	n.d.	n.d.	n.d.	4.8[(10)], 0.46[(11)], 5[(12)]	0	0%
Calcium, Dissolved (mg/l)	0.01	13	62	60	56	74	-----	-----	-----
Chromium, Dissolved (ug/l)	10	13	-----	n.d.	n.d.	n.d.	1,191[(10)], 155[(11)], 100[(12)]	0	0%
Copper, Dissolved (ug/l)	2	12	-----	n.d.	n.d.	n.d.	31[(10)], 19[(11)], 1,000[(12)]	0	0%
Hardness, Total (mg/l)	0.4	12	245	246	213	279	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	9	-----	n.d.	n.d.	n.d.	169[(10)], 6.6[(11)], 15[(12)]	0	0%
Magnesium, Dissolved (mg/l)	0.01	11	24	24	18	32	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	13	-----	n.d.	n.d.	n.d.	1.4[(10)]	0	0%
Mercury, Total (ug/l)	0.05	13	-----	n.d.	n.d.	n.d.	0.77[(11)], 2[(12)]	0	0%
Nickel, Dissolved (ug/l)	10	13	-----	n.d.	n.d.	n.d.	1,003[(10)], 111[(11)], 100[(12)]	0	0%
Selenium, Total (ug/l)	1	9	-----	2	n.d.	4	20[(4,10)], 5[(11)], 50[(12)]	0	0%
Silver, Dissolved (ug/l)	1	12	-----	n.d.	n.d.	n.d.	15[(10)], 100[(12)]	0	0%
Sodium, Dissolved (mg/l)	0.01	4	63	64	55	69	-----	-----	-----
Thallium, Dissolved (ug/l)	0.5	9	-----	n.d.	n.d.	n.d.	1,400[(10)], 6.3[(11)], 2[(12)]	0	0%
Zinc, Dissolved (ug/l)	10	13	-----	n.d.	n.d.	64	251[(10,11)], 5,000[(12)]	0	0%
Acetochlor, Total (ug/l)[(D)]	0.05	23	-----	n.d.	n.d.	2.00	-----	-----	-----
Alachlor, Total (ug/l)[(D)]	0.05	27	-----	n.d.	n.d.	n.d.	760[(10)], 76[(11)], 2[(12)]	0	0%
Atrazine, Total (ug/l)[(D)]	0.05	50	-----	n.d.	n.d.	1.00	330[(10)], 12[(11)], 3[(3)]	0	0%
Metolachlor, Total (ug/l)[(D)]	0.05	50	-----	n.d.	n.d.	1.30	390[(10)], 100[(11)]	0	0%
Pesticide Scan (ug/l)[(E)]	0.05						-----	-----	-----
Acetochlor, Total (ug/l)		10	-----	n.d.	n.d.	0.30	-----	-----	-----
Atrazine, Total (ug/l)		10	-----	n.d.	n.d.	0.40	330[(10)], 12[(11)], 3[(3)]	0	0%

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (11) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (12) Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan. Individual pesticides were not detected unless listed under pesticide scan.

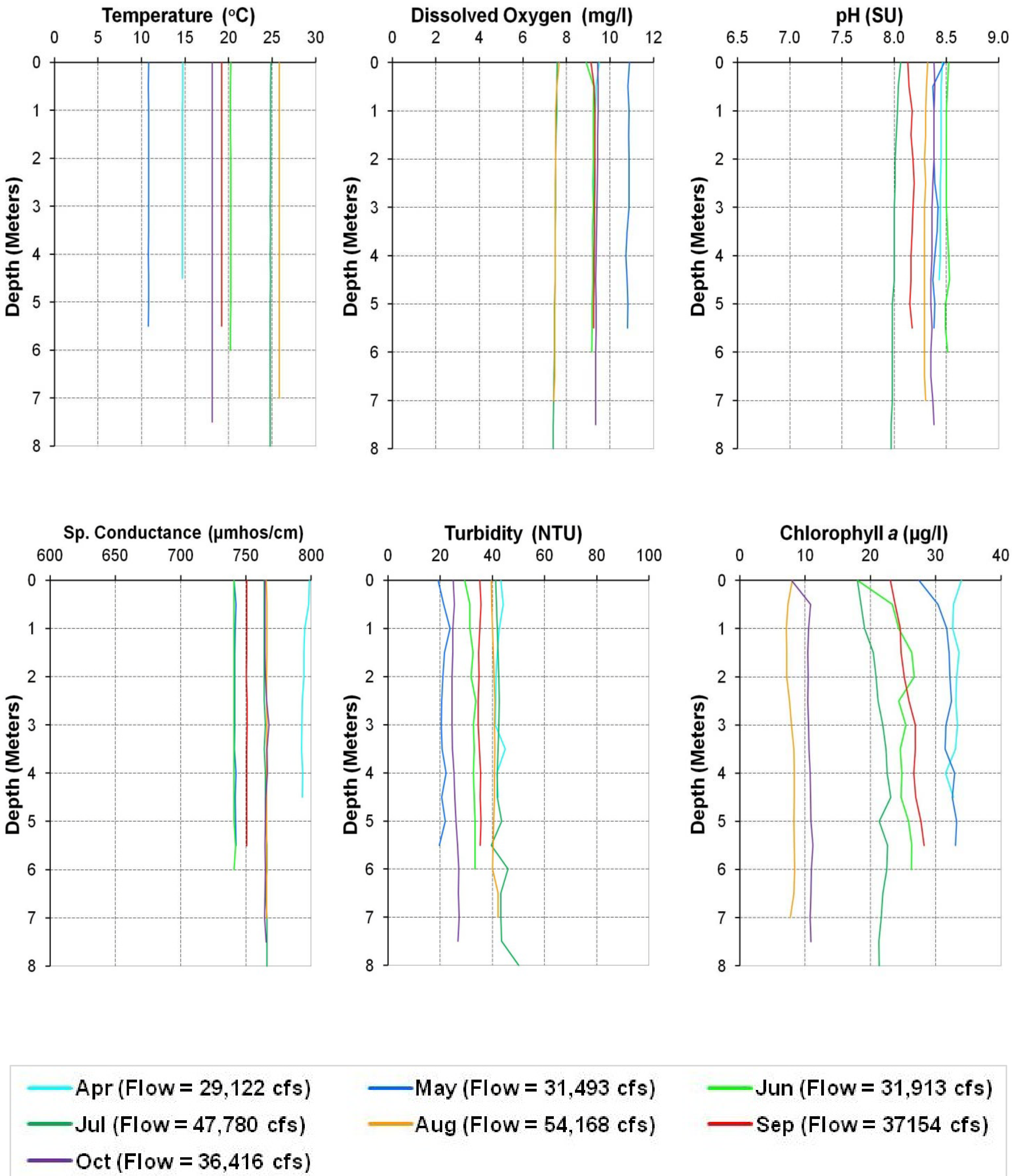
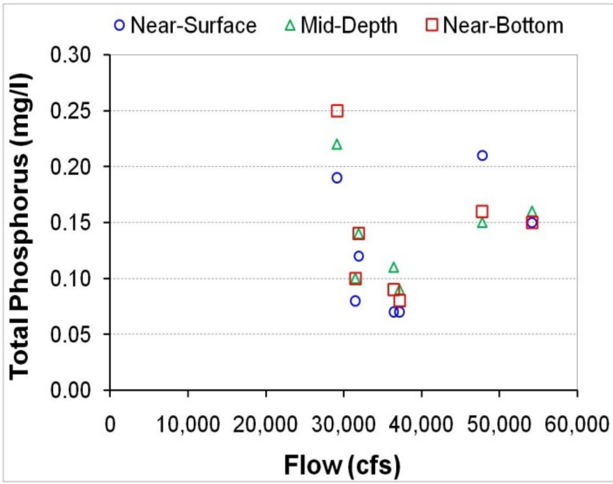
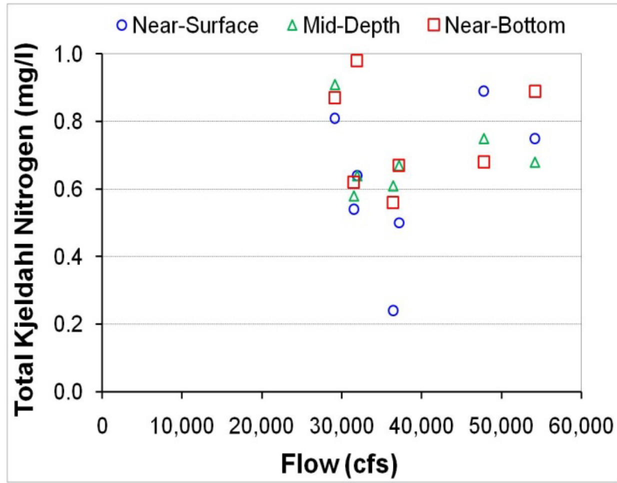
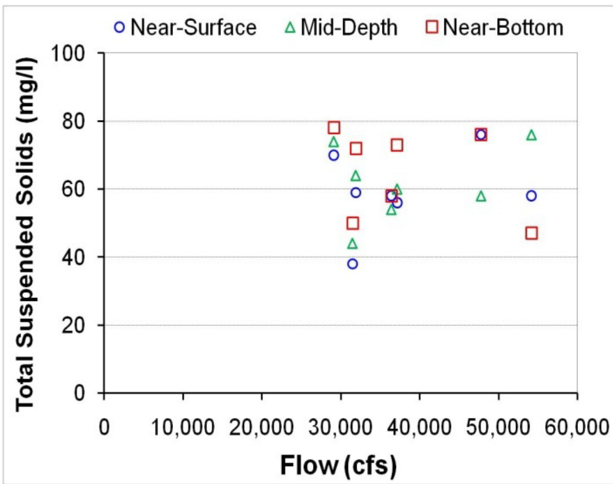
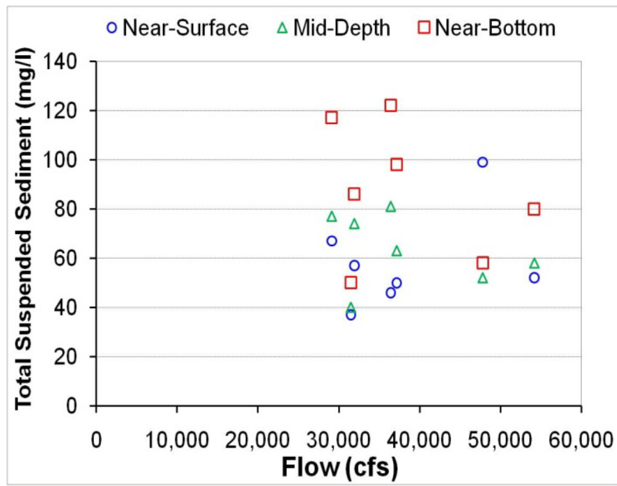


Plate 428. Water temperature, dissolved oxygen, pH, specific conductance, turbidity, and chlorophyll *a* depth profiles for the Missouri River compiled from data collected at RM753 (i.e., MORRR0753) during 2010.









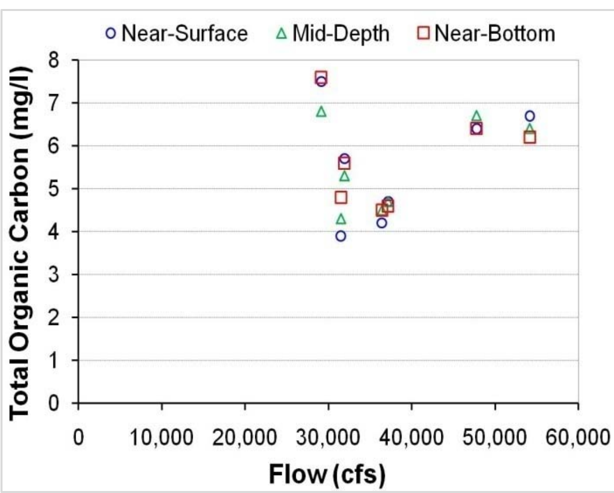


Plate 429. Comparison of flow and measured near-surface, mid-depth, and near-bottom concentrations of total phosphorus, total Kjeldahl nitrogen, total suspended solids, total suspended sediment, and total organic carbon in the Missouri River at RM753 (i.e., site MORRR0753) during 2010.

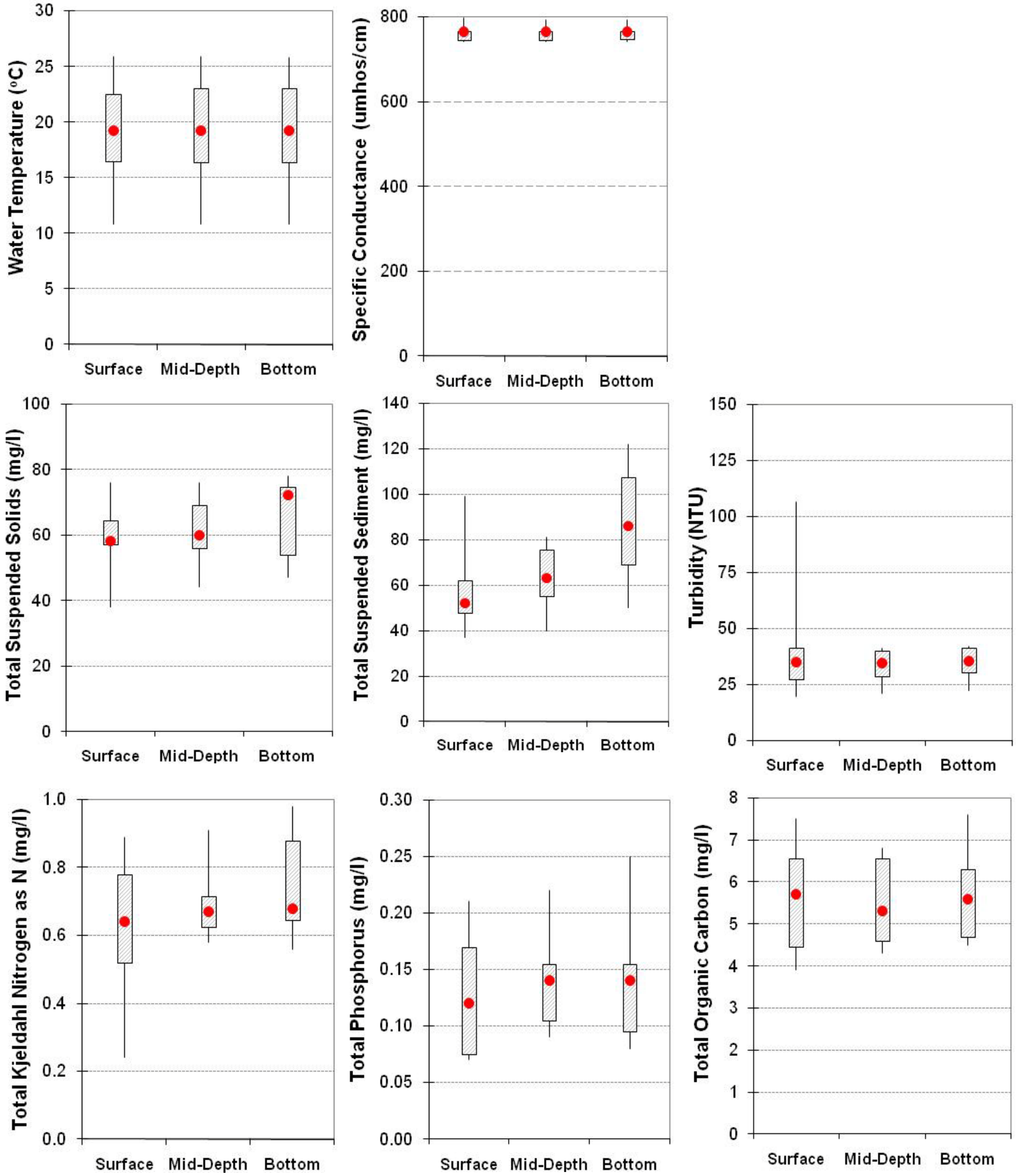


Plate 430. Box plots comparing paired surface, mid-depth, and bottom water temperature, specific conductance, total suspended solids, total suspended sediment, turbidity, total Kjeldahl nitrogen, total phosphorus, and total organic carbon measurements taken in the Missouri River at site MORRR0753 during 2010. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 431. Summary of near-surface water quality conditions monitored in the Missouri River at Decatur, Nebraska (i.e., site MORRR0691) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
USGS Gage 06601200 Discharge:									
Streamflow (cfs)	1	70	27,414	26,150	12,300	76,235	-----	-----	-----
Field Measurements:									
Water Temperature (°C)	0.1	69	14.7	15.0	0.0	29.8	32(1,5)	0	0%
Dissolved Oxygen (mg/l)	0.1	68	9.8	9.4	6.1	13.8	5(1,6)	0	0%
Dissolved Oxygen (% Sat.)	0.1	68	97.0	97.9	60.8	118.1	-----	-----	-----
Oxidation-Reduction Potential	1	37	359	354	144	508	-----	-----	-----
pH (S.U.)	0.1	67	8.2	8.3	7.7	8.7	6.5(1,6), 9.0(1,5)	0	0%
Specific Conductance (umhos/cm)	1	69	764	756	489	956	2,000(3)	0	0%
Turbidity (NTU)	1	68	55	35	4	266	-----	-----	-----
Laboratory Results:									
Alkalinity, Total (mg/l)	7	70	181	180	125	221	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	68	4.4	4.0	1.7	11.8	-----	-----	-----
CBOD 5-day (mg/l)	2	6	3	3	n.d.	5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	70	17	15	n.d.	76	-----	-----	-----
Chloride (mg/l)	1	70	17	17	8	24	-----	-----	-----
Chlorophyll *a* (ug/l)	1	7	23	23	9	38	-----	-----	-----
Color (APHA)	1	18	12	10	4	27	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	67	528	518	338	790	-----	-----	-----
Nitrogen, Ammonia Total	0.02	70	-----	0.06	n.d.	0.54	4.7 (1,5,8), 1.5 (1,7,8)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	70	1.0	0.8	n.d.	5.0	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	69	1.20	0.90	n.d.	5.00	10(2,5), 100(3,5)	0	0%
Nitrogen, Total (mg/l)	0.1	69	2.3	1.7	0.5	6.8	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	9	0.09	0.06	0.04	0.22	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	70	0.20	0.13	n.d.	1.10	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	10	0.08	0.06	0.03	0.19	-----	-----	-----
Sulfate (mg/l)	1	20	222	223	189	253	-----	-----	-----
Suspended Sediment, Total (mg/l)	4	7	106	106	53	151	-----	-----	-----
Suspended Solids, Total (mg/l)	4	70	87	46	n.d.	580	-----	-----	-----

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Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	**No. of Obs.**	**Mean**[B]	**Median**	**Min.**	**Max.**	**State WQS Criteria**[C]	**No. of WQS Exceedances**	**Percent WQS Exceedance**
Laboratory Results (Metals and Pesticides):									
Aluminum, Dissolved (mg/l)	25	12	-----	n.d	n.d.	n.d.	750[9], 87[10], 200[11]	0	0%
Antimony, Dissolved (ug/l)	0.5	13	-----	n.d	n.d.	0.7	88[9], 30[10], 6[11]	0	0%
Arsenic, Dissolved (ug/l)	1	13	2	3	n.d.	4	340[9], 16.7[10], 10[11]	0	0%
Barium, Dissolved (ug/l)	5	13	64	63	52	83	2,000[2]	0	0%
Beryllium, Dissolved (ug/l)	2	13	-----	n.d	n.d.	n.d.	130[9], 5.3[10], 4[11]	0	0%
Cadmium, Dissolved (ug/l)	0.5	18	-----	n.d	n.d.	0.5	4.4[9], 0.43[10], 5[11]	0	0%
Calcium, Dissolved (mg/l)	0.01	18	70	70	59	91	-----	-----	-----
Chromium, Dissolved (ug/l)	10	18	-----	n.d	n.d.	n.d.	1,103[9], 143[10], 100[11]	0	0%
Copper, Dissolved (ug/l)	2	17	-----	n.d	n.d.	3	29[9], 18[10], 1,000[11]	0	0%
Hardness, Total (mg/l)	0.4	16	286	274	241	381	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	13	-----	n.d	n.d.	1.0	154[9], 6.0[10], 15[11]	0	0%
Magnesium, Dissolved (mg/l)	0.01	15	28	27	24	37	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	18	-----	n.d	n.d.	n.d.	1.4[9]	0	0%
Mercury, Total (ug/l)	0.05	18	-----	n.d	n.d.	n.d.	0.77[10], 2[11]	0	0%
Nickel, Dissolved (ug/l)	10	18	-----	n.d	n.d.	n.d.	926[9], 103[10], 100[11]	0	0%
Selenium, Total (ug/l)	1	13	3	3	1	4	20[3,9], 5[10], 50[11]	0	0%
Silver, Dissolved (ug/l)	1	18	-----	n.d	n.d.	n.d.	13[9], 100[11]	0	0%
Sodium, Dissolved (mg/l)	0.01	6	60	62	51	66	-----	-----	-----
Thallium, Dissolved (ug/l)	0.5	13	-----	n.d	n.d.	n.d.	1,400[9], 6.3[10], 2[11]	0	0%
Zinc, Dissolved (ug/l)	10	18	-----	n.d	n.d.	68	232[9,10], 5,000[11]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	29	-----	n.d	n.d.	1.40	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	31	-----	n.d	n.d.	0.20	760[9], 76[10], 2[2]	0	0%
Atrazine, Total (ug/l)[D]	0.05	60	-----	n.d.	n.d.	1.30	330[9], 12[10], 3[2]	0	0%
Metolachlor, Total (ug/l)[D]	0.05	60	-----	n.d	n.d.	2.50	390[9], 100[10]	0	0%
Pesticide Scan (ug/l)[E]	0.05						-----	-----	-----
Atrazine, Total (ug/l)		10	-----	n.d	n.d.	0.19	330[9], 12[10], 3[2]	0	0%
Prometon, Total (ug/l)		10	-----	n.d	n.d.	0.10	-----	-----	-----

n.d. = Not detected.

[A] Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for the protection of Class I Warmwater Aquatic Life (Nebraska).
- [2] Criteria for the protection of domestic water supply waters.
- [3] Criteria for the protection of agricultural water supply waters.
- [4] Criteria for the protection of commerce and industry waters.
- [5] Daily maximum criterion (monitoring results directly comparable to criterion).
- [6] Daily minimum criterion (monitoring results directly comparable to criterion).
- [7] 30-day average criterion (monitoring results not directly comparable to criterion).
- [8] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- [9] Acute criterion for aquatic life.
- [10] Chronic criterion for aquatic life.
- [11] Criterion for the protection of human health.

Note: Some of Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] Immunoassay analysis.

[E] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

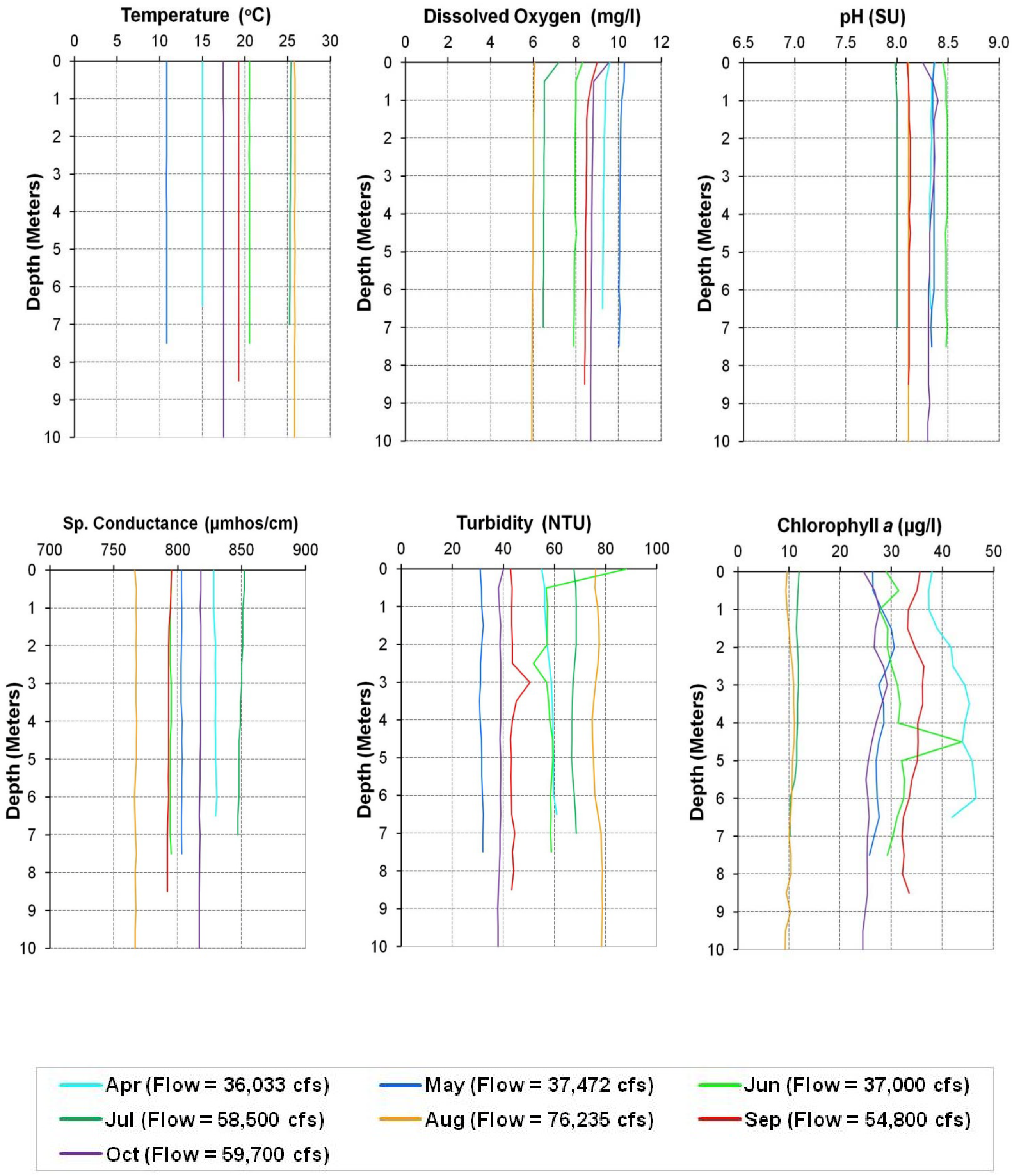

Plate 432. Water temperature, dissolved oxygen, pH, specific conductance, turbidity, and chlorophyll *a* depth profiles for the Missouri River compiled from data collected at RM691 (i.e., MORRR0691) during 2010.

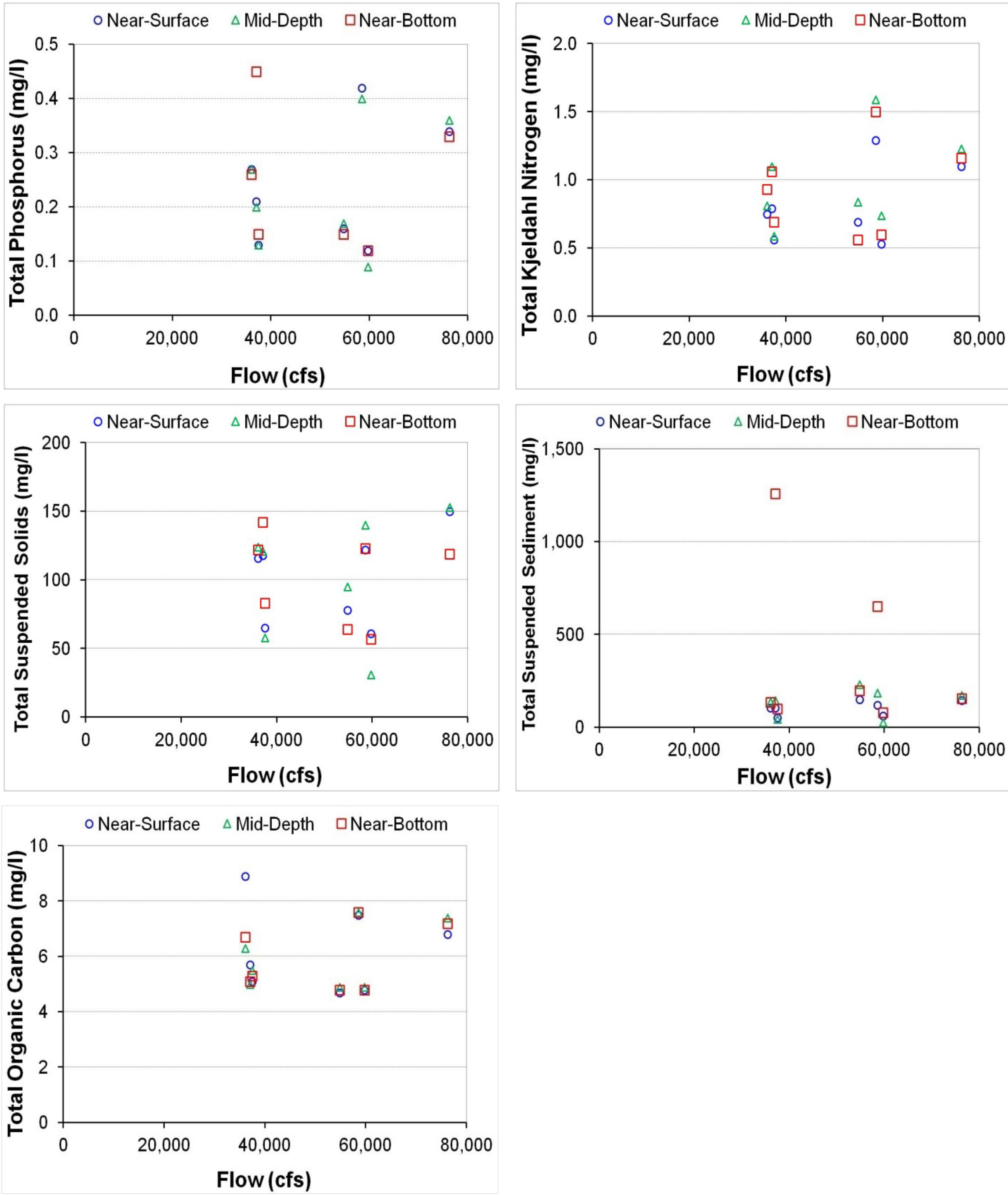

Plate 433. Comparison of flow and measured near-surface, mid-depth, and near-bottom concentrations of total phosphorus, total Kjeldahl nitrogen, total suspended solids, total suspended sediment, and total organic carbon in the Missouri River at RM691 (i.e., site MORRR0691) during 2010.

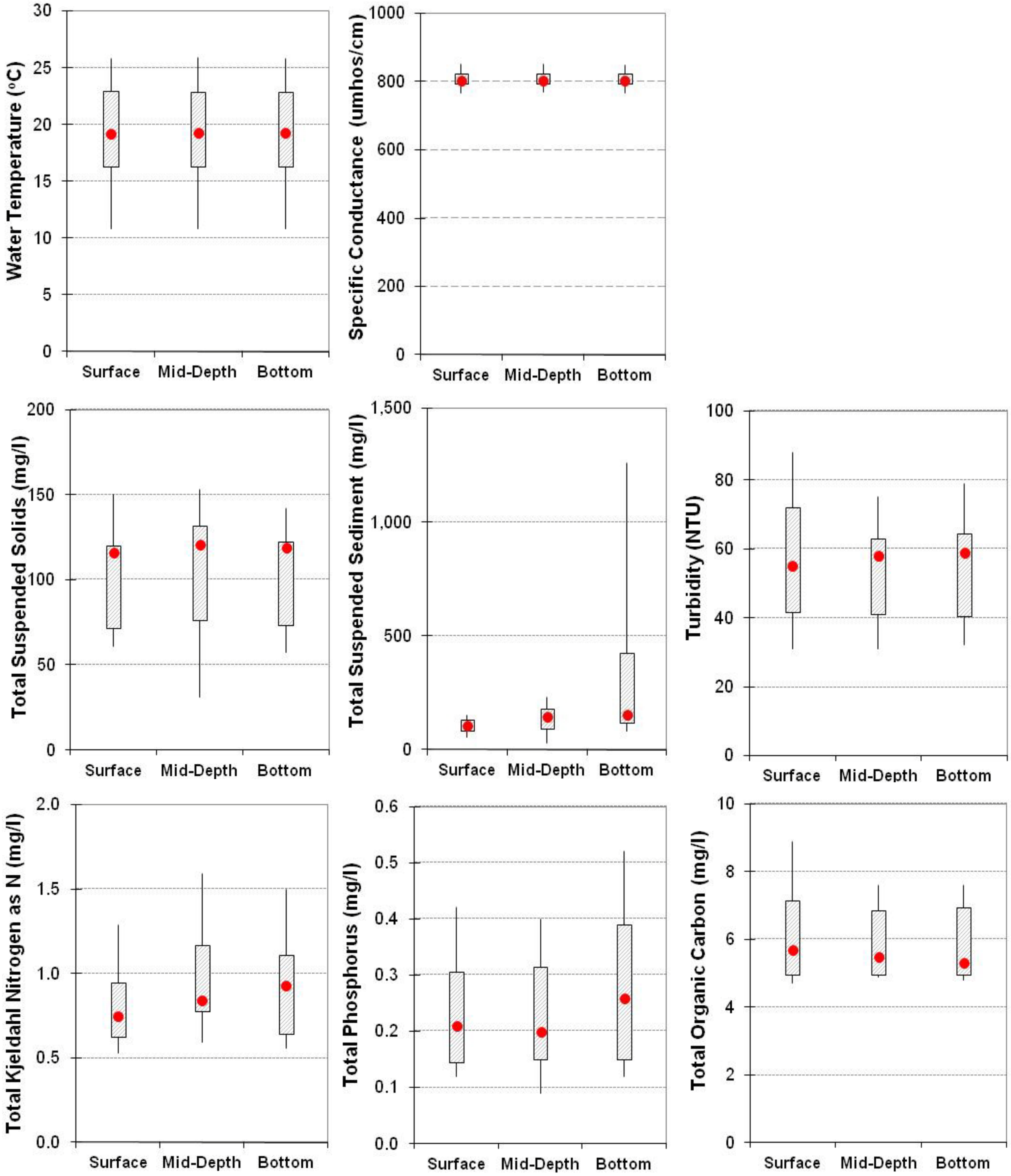

Plate 434. Box plots comparing paired surface, mid-depth, and bottom water temperature, specific conductance, total suspended solids, total suspended sediment, turbidity, total Kjeldahl nitrogen, total phosphorus, and total organic carbon measurements taken in the Missouri River at site MORRR0691 during 2010. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 435. Summary of near-surface water quality conditions monitored in the Missouri River at Omaha, Nebraska (i.e., site MORRR0619) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
USGS Gage 06610000 Discharge:									
Streamflow (cfs)	1	72	31,781	29,300	11,600	96,611	-----	-----	-----
Field Measurements:									
Water Temperature (°C)	0.1	70	14.4	15.4	0.0	27.8	32(1,5)	0	0%
Dissolved Oxygen (mg/l)	0.1	69	9.7	9.2	5.4	14.4	5(1,6)	0	0%
Dissolved Oxygen (% Sat.)	0.1	69	94.3	95.7	66.9	115.1	-----	-----	-----
Oxidation-Reduction Potential	1	36	386	382	168	543	-----	-----	-----
pH (S.U.)	0.1	67	8.2	8.2	7.4	8.7	6.5(1,6), 9.0(1,5)	0	0%
Specific Conductance (umhos/cm)	1	70	745	749	470	899	2,000(3)	0	0%
Turbidity (NTU)	1	70	133	50	4	1,324	-----	-----	-----
Laboratory Results:									
Alkalinity, Total (mg/l)	7	72	190	190	140	250	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	70	4.7	4.2	2.3	17.2	-----	-----	-----
CBOD 5-day (mg/l)	2	6	-----	2	n.d.	3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	72	23	17	n.d.	98	-----	-----	-----
Chloride (mg/l)	1	71	17	17	7	23	-----	-----	-----
Chlorophyll *a* (ug/l)	1	7	16	16	1	32	-----	-----	-----
Color (APHA)	1	19	12	11	4	23	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	69	513	510	328	644	-----	-----	-----
Nitrogen, Ammonia Total	0.02	72	-----	0.06	n.d.	0.79	5.7 (1,5,8), 1.5 (1,7,8)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	72	1.2	0.8	n.d.	5.1	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	71	1.88	1.70	n.d.	5.40	10(2,5), 100(3,5)	0	0%
Nitrogen, Total (mg/l)	0.1	68	3.2	2.6	0.6	8.7	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	9	0.09	0.08	0.03	0.20	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	72	0.33	0.18	0.05	2.40	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	22	0.07	0.06	0.02	0.20	-----	-----	-----
Sulfate (mg/l)	1	23	195	202	116	240	-----	-----	-----
Suspended Sediment, Total (mg/l)	4	7	150	143	69	303	-----	-----	-----
Suspended Solids, Total (mg/l)	4	72	187	80	15	1,772	-----	-----	-----

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Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Laboratory Results (Metals and Pesticides):									
Aluminum, Dissolved (mg/l)	25	12	-----	n.d.	n.d.	60	750(9), 87(10), 200(11)	0	0%
Antimony, Dissolved (ug/l)	0.5	13	-----	n.d.	n.d.	2	88(9), 30(10), 6(11)	0	0%
Arsenic, Dissolved (ug/l)	1	13	2	2	n.d.	4	340(9), 16.7(10), 10(11)	0	0%
Barium, Dissolved (ug/l)	5	13	82	74	60	146	2,000(2)	0	0%
Beryllium, Dissolved (ug/l)	2	13	-----	n.d.	n.d.	n.d.	130(9), 5.3(10), 4(11)	0	0%
Cadmium, Dissolved (ug/l)	0.5	18	-----	n.d.	n.d.	3	15(9), 0.50(10), 5(11)	0, 2, 0	0%, 11%, 0%
Calcium, Dissolved (mg/l)	0.01	18	71	70	59	94	-----	-----	-----
Chromium, Dissolved (ug/l)	10	18	-----	n.d.	n.d.	n.d.	1,156(9), 177(10), 100(11)	0	0%
Copper, Dissolved (ug/l)	2	17	-----	n.d.	n.d.	n.d.	35(9), 21(10), 1,000(11)	0	0%
Hardness, Total (mg/l)	0.4	16	286	275	231	379	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	13	-----	n.d.	n.d.	1	190(9), 7.4(10), 15(11)	0	0%
Magnesium, Dissolved (mg/l)	0.01	15	27	26	22	35	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	18	-----	n.d.	n.d.	n.d.	1.4(9)	0	0%
Mercury, Total (ug/l)	0.05	18	-----	n.d.	n.d.	n.d.	0.77(10), 2(11)	0	0%
Nickel, Dissolved (ug/l)	10	18	-----	n.d.	n.d.	4	1,102(9), 122(10), 100(11)	0	0%
Selenium, Total (ug/l)	1	13	4	4	2	7	20(3,9), 5(10), 50(11)	0, 1, 0	0%, 8%, 0%
Silver, Dissolved (ug/l)	1	17	-----	n.d.	n.d.	n.d.	20(9), 100(11)	0	0%
Sodium, Dissolved (mg/l)	0.01	6	56	58	48	62	-----	-----	-----
Thallium, Dissolved (ug/l)	0.5	13	-----	n.d.	n.d.	n.d.	1,400(9), 6.3(10), 2(11)	0	0%
Zinc, Dissolved (ug/l)	10	18	-----	n.d.	n.d.	39	282(9,10), 5,000(11)	0	0%
Acetochlor, Total (ug/l)(D)	0.05	30	-----	n.d.	n.d.	0.30	-----	-----	-----
Alachlor, Total (ug/l)(D)	0.05	29	-----	n.d.	n.d.	0.30	760(9), 76(10), 2(2)	0	0%
Atrazine, Total (ug/l)(D)	0.05	59	-----	n.d.	n.d.	2.10	330(9), 12(10), 3(2)	0	0%
Metolachlor, Total (ug/l)(D)	0.05	59	-----	n.d.	n.d.	1.60	390(9), 100(10)	0	0%
Pesticide Scan (ug/l)(E)	0.05						-----	-----	-----
Acetochlor, Total (ug/l)		12	-----	n.d.	n.d.	0.30	-----	-----	-----
Atrazine, Total (ug/l)		12	-----	n.d.	n.d.	0.55	330(9), 12(10), 3(2)	0	0%
Metolachlor, Total (ug/l)		12	-----	n.d.	n.d.	0.34	390(9), 100(10)	0	0%

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of Class I Warmwater Aquatic Life (Nebraska).
(2) Criteria for the protection of domestic water supply waters.
(3) Criteria for the protection of agricultural water supply waters.
(4) Criteria for the protection of commerce and industry waters.
(5) Daily maximum criterion (monitoring results directly comparable to criterion).
(6) Daily minimum criterion (monitoring results directly comparable to criterion).
(7) 30-day average criterion (monitoring results not directly comparable to criterion).
(8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(9) Acute criterion for aquatic life.
(10) Chronic criterion for aquatic life.
(11) Criterion for the protection of human health.

Note: Some of Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

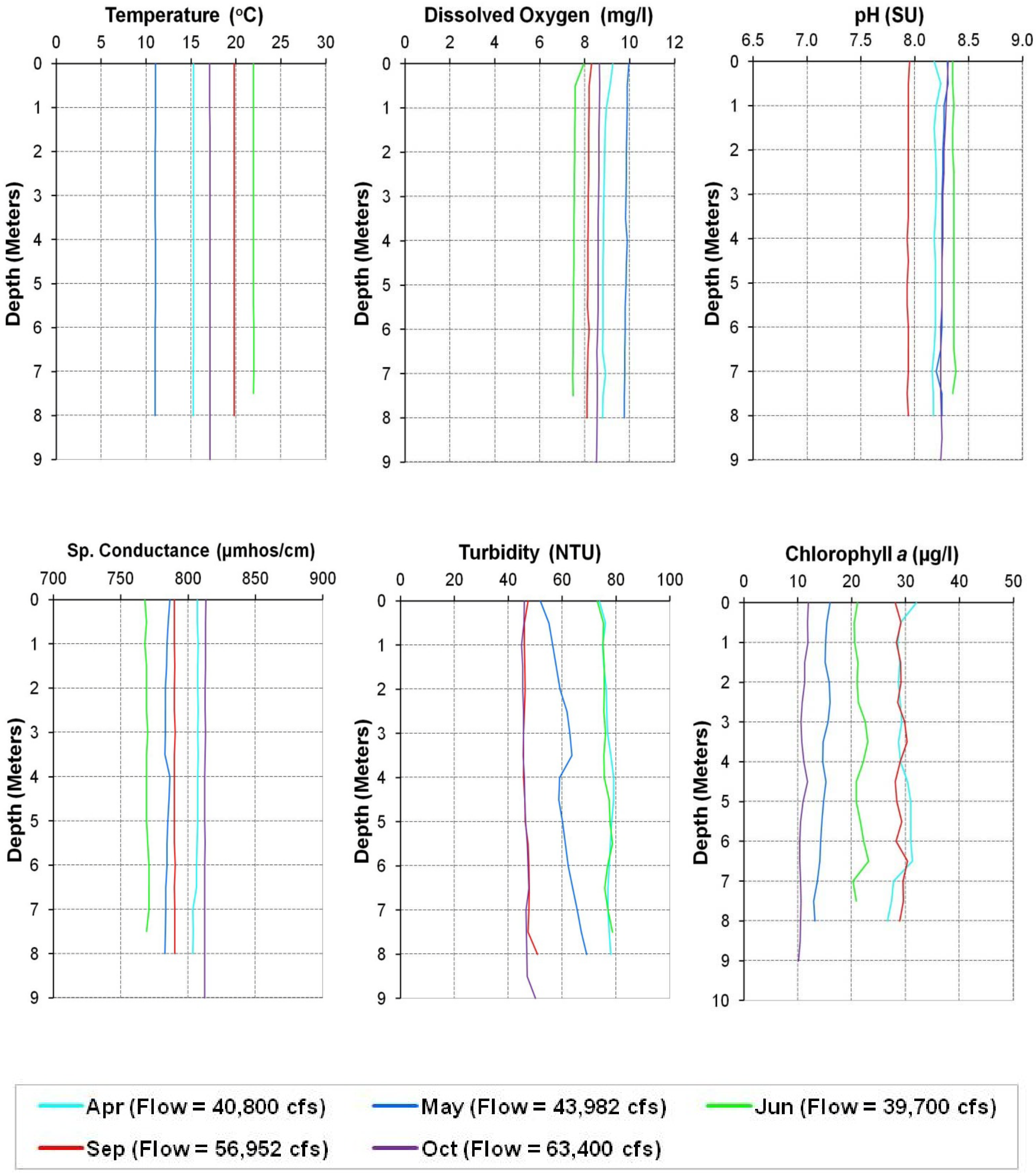

Plate 436. Water temperature, dissolved oxygen, pH, specific conductance, turbidity, and chlorophyll *a* depth profiles for the Missouri River compiled from data collected at RM619 (i.e., MORRR0619) during 2010.

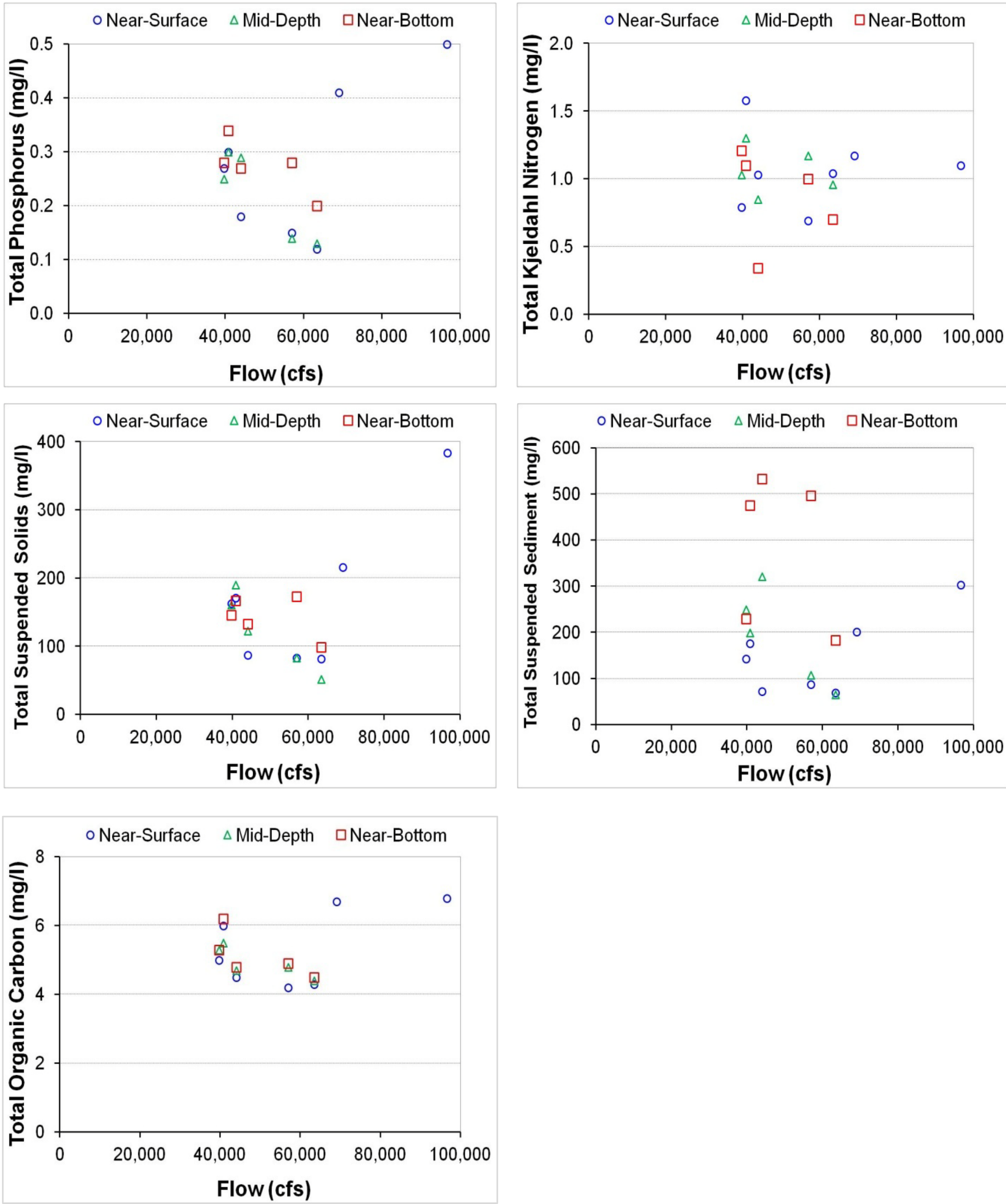

Plate 437. Comparison of flow and measured near-surface, mid-depth, and near-bottom concentrations of total phosphorus, total Kjeldahl nitrogen, total suspended solids, total suspended sediment, and total organic carbon in the Missouri River at RM619 (i.e., site MORRR0619) during 2010.

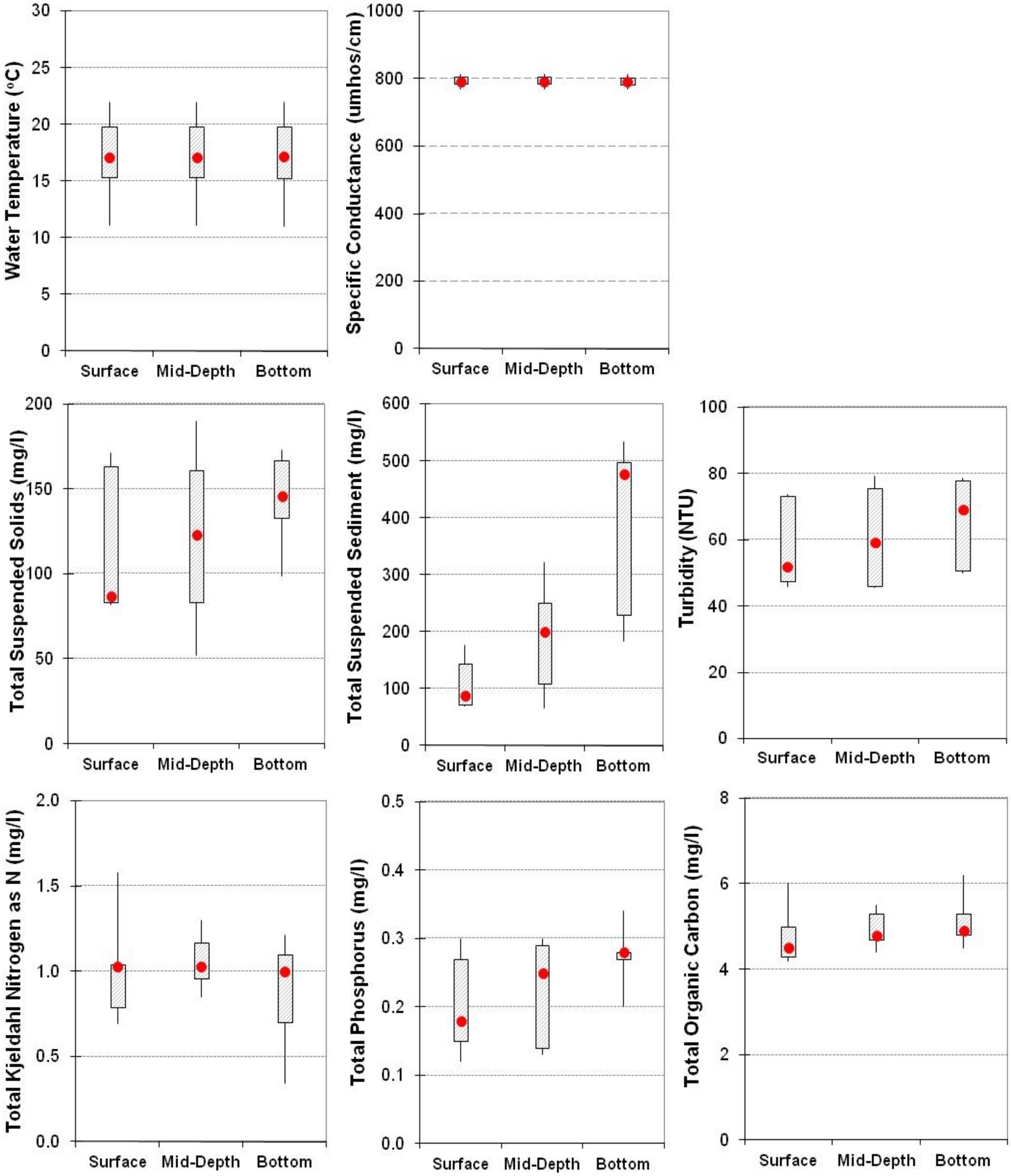

Plate 438. Box plots comparing paired surface, mid-depth, and bottom water temperature, specific conductance, total suspended solids, total suspended sediment, turbidity, total Kjeldahl nitrogen, total phosphorus, and total organic carbon measurements taken in the Missouri River at site MORRR0619 during 2010. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 439. Summary of near-surface water quality conditions monitored in the Missouri River at Nebraska City, Nebraska (i.e., site MORRR0563) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
USGS Gage 06807000 Discharge:									
Streamflow (cfs)	1	71	39,050	35,300	16,000	117,000	-----	-----	-----
Field Measurements:									
Water Temperature (°C)	0.1	69	14.6	15.5	0.0	28.2	32(1,5)	0	0%
Dissolved Oxygen (mg/l)	0.1	68	9.5	9.1	5.8	14.7	5(1,6)	0	0%
Dissolved Oxygen (% Sat.)	0.1	68	92.8	94.3	68.5	104.4	-----	-----	-----
Oxidation-Reduction Potential	1	34	389	380	264	535	-----	-----	-----
pH (S.U.)	0.1	68	8.2	8.2	7.5	8.7	6.5(1,6), 9.0(1,5)	0	0%
Specific Conductance (umhos/cm)	1	69	717	734	472	862	2,000(3)	0	0%
Turbidity (NTU)	1	67	117	55	2	636	-----	-----	-----
Laboratory Results:									
Alkalinity, Total (mg/l)	7	71	189	191	130	242	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	69	4.9	4.2	2.0	17.8	-----	-----	-----
CBOD 5-day (mg/l)	2	5	2	2	2	3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	71	26	19	n.d.	137	-----	-----	-----
Chloride (mg/l)	1	71	25	25	8	48	-----	-----	-----
Chlorophyll *a* (ug/l)	1	6	23	22	5	39	-----	-----	-----
Color (APHA)	1	18	12	10	5	21	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	68	482	486	318	660	-----	-----	-----
Nitrogen, Ammonia Total	0.02	71	-----	0.10	n.d.	0.66	5.7 (1,5,8), 1.5 (1,7,8)	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	71	1.4	1.1	0.6	5.4	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	70	1.82	1.85	0.04	4.00	10(2,5), 100(3,5)	0	0%
Nitrogen, Total (mg/l)	0.1	70	3.3	3.0	0.8	8.7	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	8	0.12	0.09	0.06	0.21	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	71	0.43	0.31	0.09	2.60	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	21	0.11	0.10	0.03	0.21	-----	-----	-----
Sulfate (mg/l)	1	22	171	181	99	210	-----	-----	-----
Suspended Sediment, Total (mg/l)	4	6	359	171	101	1,344	-----	-----	-----
Suspended Solids, Total (mg/l)	4	71	230	100	4	1,888	-----	-----	-----

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Plate Continued from Previous Page									
Parameter	**Monitoring Results**						**Water Quality Standards Attainment**		
	Detection Limit[A]	**No. of Obs.**	**Mean**[B]	**Median**	**Min.**	**Max.**	**State WQS Criteria**[C]	**No. of WQS Exceedances**	**Percent WQS Exceedance**
Laboratory Results (Metals and Pesticides):									
Aluminum, Dissolved (mg/l)	25	12	-----	n.d.	n.d.	50	750[9], 87[10], 200[11]	0	0%
Antimony, Dissolved (ug/l)	0.5	13	-----	n.d.	n.d.	1.0	88[9], 30[10], 6[11]	0	0%
Arsenic, Dissolved (ug/l)	1	13	4	6	1	6	340[9], 16.7[10], 10[11]	0	0%
Barium, Dissolved (ug/l)	5	13	100	105	69	135	2,000[2]	0	0%
Beryllium, Dissolved (ug/l)	2	13	-----	n.d.	n.d.	n.d.	130[9], 5.3[10], 4[11]	0	0%
Cadmium, Dissolved (ug/l)	0.5	18	-----	n.d.	n.d.	n.d.	15[9], 0.49[10], 5[11]	0	0%
Calcium, Dissolved (mg/l)	0.01	18	68	68	54	80	-----	-----	-----
Chromium, Dissolved (ug/l)	10	18	-----	n.d.	n.d.	n.d.	1,327[9], 173[10], 100[11]	0	0%
Copper, Dissolved (ug/l)	2	17	-----	n.d.	n.d.	3	34[9], 21[10], 1,000[11]	0	0%
Hardness, Total (mg/l)	0.4	16	268	268	215	311	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	13	-----	n.d.	n.d.	n.d.	185[9], 7.2[10], 15[11]	0	0%
Magnesium, Dissolved (mg/l)	0.01	15	24	24	19	29	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	18	-----	n.d.	n.d.	n.d.	1.4[9]	0	0%
Mercury, Total (ug/l)	0.05	18	-----	n.d.	n.d.	n.d.	0.77[10], 2[11]	0	0%
Nickel, Dissolved (ug/l)	10	18	-----	n.d.	n.d.	n.d.	1,078[9], 120[10], 100[11]	0	0%
Selenium, Total (ug/l)	1	14	4	4	2	5	20[3,9], 5[10], 50[11]	0	0%
Silver, Dissolved (ug/l)	1	17	-----	n.d.	n.d.	n.d.	19[9], 100[11]	0	0%
Sodium, Dissolved (mg/l)	0.01	5	59	62	52	65	-----	-----	-----
Thallium, Dissolved (ug/l)	0.5	13	-----	n.d.	n.d.	n.d.	1,400[9], 6.3[10], 2[11]	0	0%
Zinc, Dissolved (ug/l)	10	18	-----	n.d.	n.d.	72	270[9,10], 5,000[11]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	29	-----	n.d.	n.d.	2.50	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	29	-----	n.d.	n.d.	0.30	760[9], 76[10], 2[2]	0	0%
Atrazine, Total (ug/l)[D]	0.05	58	-----	n.d.	n.d.	4.20	330[9], 12[10], 3[2]	0	0%
Metolachlor, Total (ug/l)[D]	0.05	58	-----	n.d.	n.d.	2.40	390[9], 100[10]	0	0%
Pesticide Scan (ug/l)[E]	0.05						-----	-----	-----
Acetochlor, Total (ug/l)		12	-----	n.d.	n.d.	0.20	-----	-----	-----
Atrazine, Total (ug/l)		12	-----	n.d.	n.d.	1.20	330[9], 12[10], 3[2]	0	0%
Metolachlor, Total (ug/l)		12	-----	n.d.	n.d.	0.51	390[9], 100[10]	0	0%

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Class I Warmwater Aquatic Life (Nebraska).
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of agricultural water supply waters.
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (9) Acute criterion for aquatic life.
- (10) Chronic criterion for aquatic life.
- (11) Criterion for the protection of human health.

Note: Some of Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

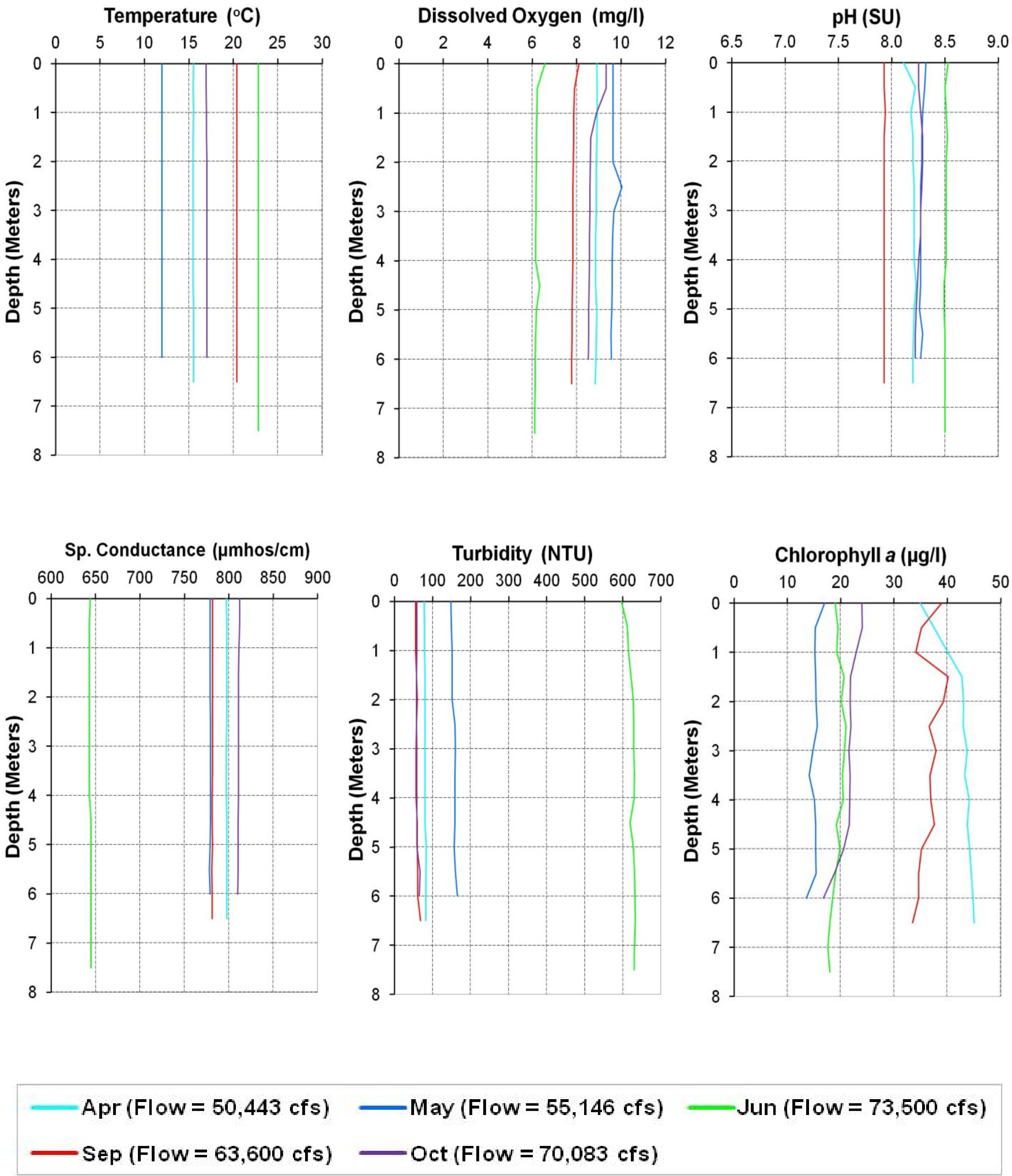

Plate 440. Water temperature, dissolved oxygen, pH, specific conductance, turbidity, and chlorophyll *a* depth profiles for the Missouri River compiled from data collected at RM563 (i.e., MORRR0563) during 2010.

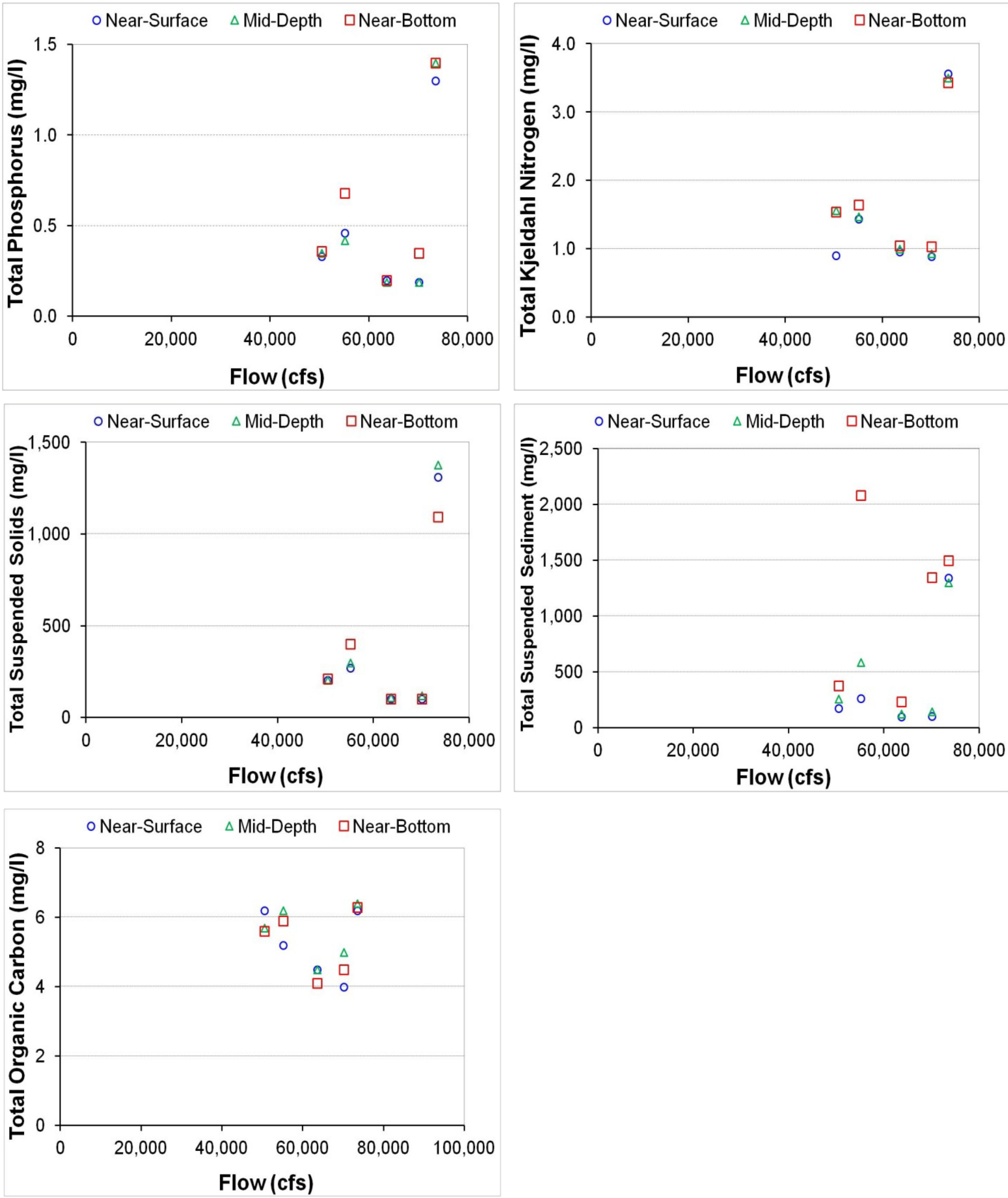

Plate 441. Comparison of flow and measured near-surface, mid-depth, and near-bottom concentrations of total phosphorus, total Kjeldahl nitrogen, total suspended solids, total suspended sediment, and total organic carbon in the Missouri River at RM563 (i.e., site MORRR0563) during 2010.

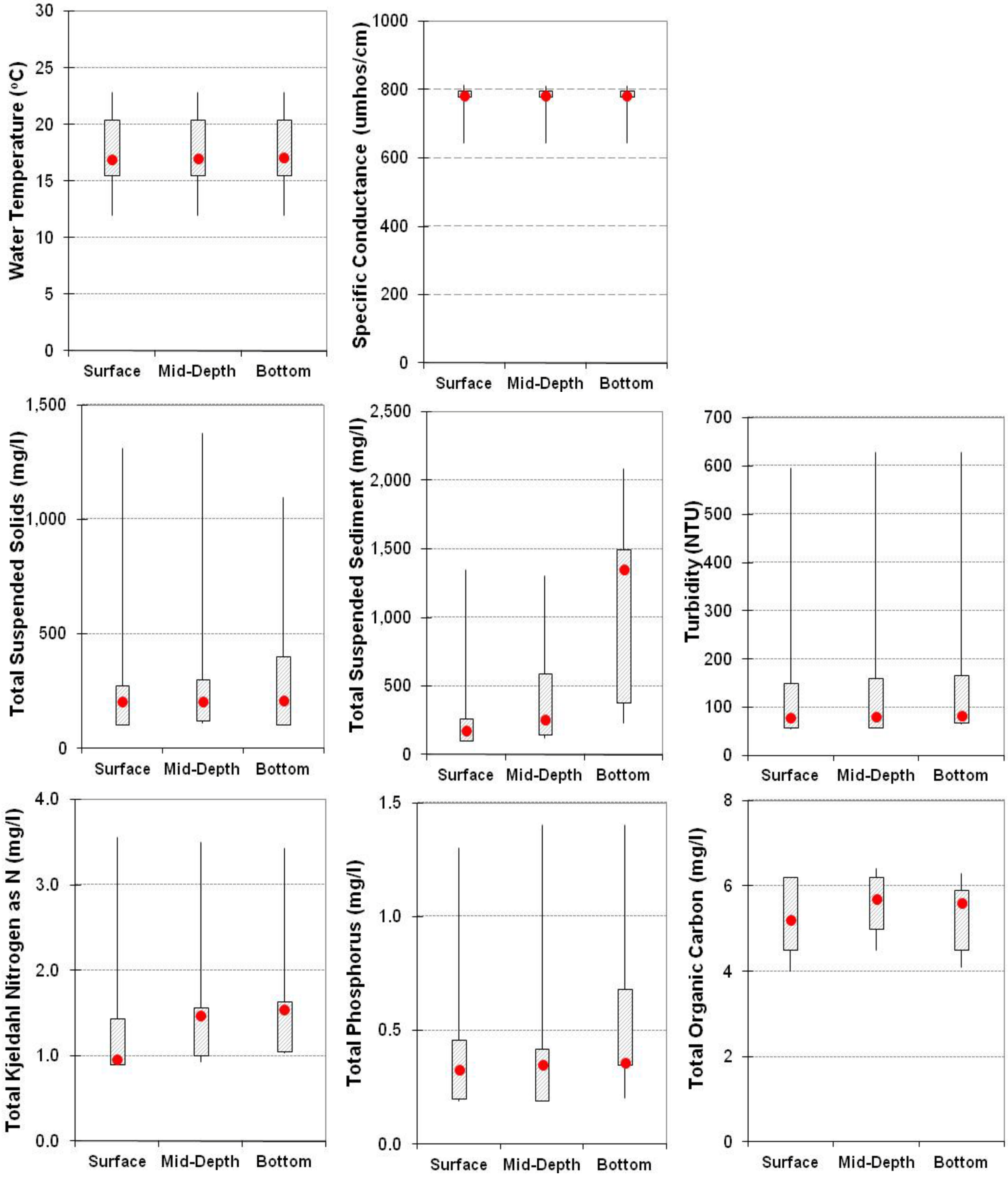

Plate 442. Box plots comparing paired surface, mid-depth, and bottom water temperature, specific conductance, total suspended solids, total suspended sediment, turbidity, total Kjeldahl nitrogen, total phosphorus, and total organic carbon measurements taken in the Missouri River at site MORRR0619 during 2010. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 443. Summary of near-surface water quality conditions monitored in the Missouri River at Rulo, Nebraska (i.e., site MORRR0498) during the 5-year period 2006 through 2010.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[(A)]	No. of Obs.	Mean[(B)]	Median	Min.	Max.	State WQS Criteria[(C)]	No. of WQS Exceedances	Percent WQS Exceedance
USGS Gage 06813500 Discharge:									
Streamflow (cfs)	1	71	42,458	35,500	17,500	131,000	-----	-----	-----
Field Measurements:									
Water Temperature (°C)	0.1	69	15.4	16.6	0.0	29.4	32[(1,5)]	0	0%
Dissolved Oxygen (mg/l)	0.1	68	9.3	8.8	5.2	14.3	5[(1,6)]	0	0%
Dissolved Oxygen (% Sat.)	0.1	67	92.4	93.9	65.9	107.2	-----	-----	-----
Oxidation-Reduction Potential	1	37	381	374	149	505	-----	-----	-----
pH (S.U.)	0.1	68	8.1	8.2	7.5	8.6	6.5[(1,6)], 9.0[(1,5)]	0	0%
Specific Conductance (umhos/cm)	1	69	713	739	384	828	2,000[(3)]	0	0%
Turbidity (NTU)	1	68	140	66	4	2,125	-----	-----	-----
Laboratory Results:									
Alkalinity, Total (mg/l)	7	71	190	191	130	240	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	69	4.4	4.0	1.4	13.5	-----	-----	-----
CBOD 5-day (mg/l)	2	6	2	3	n.d,	3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	71	22	16	n.d.	99	-----	-----	-----
Chloride (mg/l)	1	70	23	22	7	63	-----	-----	-----
Chlorophyll *a* (ug/l)	1	8	15	17	n.d.	28	-----	-----	-----
Color (APHA)	1	19	12	11	5	22	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	68	479	482	318	654	-----	-----	-----
Nitrogen, Ammonia Total	0.02	71	-----	0.06	n.d.	0.56	6.9 [(1,5,8)], 1.7 [(1,7,8)]	0	0%
Nitrogen, Kjeldahl Total (mg/l)	0.1	71	1.3	1.0	0.6	5.0	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/l)	0.02	70	2.01	2.00	0.03	4.30	10[(2,5)], 100[(3,5)]	0	0%
Nitrogen, Total (mg/l)	0.1	70	3.3	3.0	0.7	8.3	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	9	0.12	0.11	0.06	0.19	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	71	0.42	0.30	0.11	2.80	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	22	0.11	0.10	0.05	0.21	-----	-----	-----
Sulfate (mg/l)	1	23	166	164	86	207	-----	-----	-----
Suspended Sediment, Total (mg/l)	4	7	461	345	143	981	-----	-----	-----
Suspended Solids, Total (mg/l)	4	71	244	120	14	2,164	-----	-----	-----

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Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Laboratory Results (Metals and Pesticides):									
Aluminum, Dissolved (mg/l)	25	12	-----	n.d.	n.d.	2,750	750[9], 87[10], 200[11]	1	8%
Antimony, Dissolved (ug/l)	0.5	13	-----	n.d.	n.d.	1.2	88[9], 30[10], 6[11]	0	0%
Arsenic, Dissolved (ug/l)	1	13	3	3	2	6	340[9], 16.7[10], 10[11]	0	0%
Barium, Dissolved (ug/l)	5	13	103	102	69	136	2,000[2]	0	0%
Beryllium, Dissolved (ug/l)	2	13	-----	n.d.	n.d.	n.d.	130[9], 5.3[10], 4[11]	0	0%
Cadmium, Dissolved (ug/l)	0.5	18	-----	n.d.	n.d.	n.d.	15[9], 0.48[10], 5[11]	0, 2, 0	0%, 11%, 0%
Calcium, Dissolved (mg/l)	0.01	18	68	68	58	82	-----	-----	-----
Chromium, Dissolved (ug/l)	10	18	-----	n.d.	n.d.	20	1,291[9], 168 [10], 100[11]	0	0%
Copper, Dissolved (ug/l)	2	18	-----	n.d.	n.d.	30	33[9], 20[10], 1,000[11]	0, 1, 0	0%, 6%, 0%
Hardness, Total (mg/l)	0.4	16	266	259	226	331	-----	-----	-----
Lead, Dissolved (ug/l)	0.5	13	-----	n.d.	n.d.	0.6	179[9], 7.0[10], 15[11]	0	0%
Magnesium, Dissolved (mg/l)	0.01	15	24	24	20	31	-----	-----	-----
Mercury, Dissolved (ug/l)	0.05	18	-----	n.d.	n.d.	n.d.	1.4[9]	0	0%
Mercury, Total (ug/l)	0.05	17	-----	n.d.	n.d.	n.d.	0.77[10], 2[11]	0	0%
Nickel, Dissolved (ug/l)	10	18	-----	n.d.	n.d.	70	1,050[9], 116[10], 100[11]	0	0%
Selenium, Total (ug/l)	1	13	3	4	2	5	20[3,9], 5[10], 50[11]	0, 1, 0	0%, 8%, 0%
Silver, Dissolved (ug/l)	1	17	-----	n.d.	n.d.	n.d.	18[9], 100[11]	0	0%
Sodium, Dissolved (mg/l)	0.01	5	57	61	48	64	-----	-----	-----
Thallium, Dissolved (ug/l)	0.5	13	-----	n.d.	n.d.	n.d.	1,400[9], 6.3[10], 2[11]	0	0%
Zinc, Dissolved (ug/l)	10	18	-----	n.d.	n.d.	41	262[9,10], 5,000[11]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	30	-----	n.d.	n.d.	2.40	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	28	-----	n.d.	n.d.	0.20	760[9], 76[10], 2[2]	0	0%
Atrazine, Total (ug/l)[D]	0.05	58	-----	n.d.	n.d.	5.10	330[9], 12[10], 3[2]	0, 0, 2	0%, 0%, 3%
Metolachlor, Total (ug/l)[D]	0.05	58	-----	n.d.	n.d.	2.00	390[9], 100[10]	0	0%
Pesticide Scan (ug/l)[E]	0.05	12					-----	-----	-----
Acetochlor, Total (ug/l)		12	-----	n.d.	n.d.	0.70	-----	-----	-----
Atrazine, Total (ug/l)		12	-----	n.d.	n.d.	4.80	330[9], 12[10], 3[2]	0, 0, 1	0%, 0%, 8%
Metolachlor, Total (ug/l)		12	-----	n.d.	n.d.	0.45	390[9], 100[10]	0	0%

Plate Continued from Previous Page

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Class I Warmwater Aquatic Life (Nebraska).
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of agricultural water supply waters.
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (9) Acute criterion for aquatic life.
- (10) Chronic criterion for aquatic life.
- (11) Criterion for the protection of human health.

Note: Some of Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

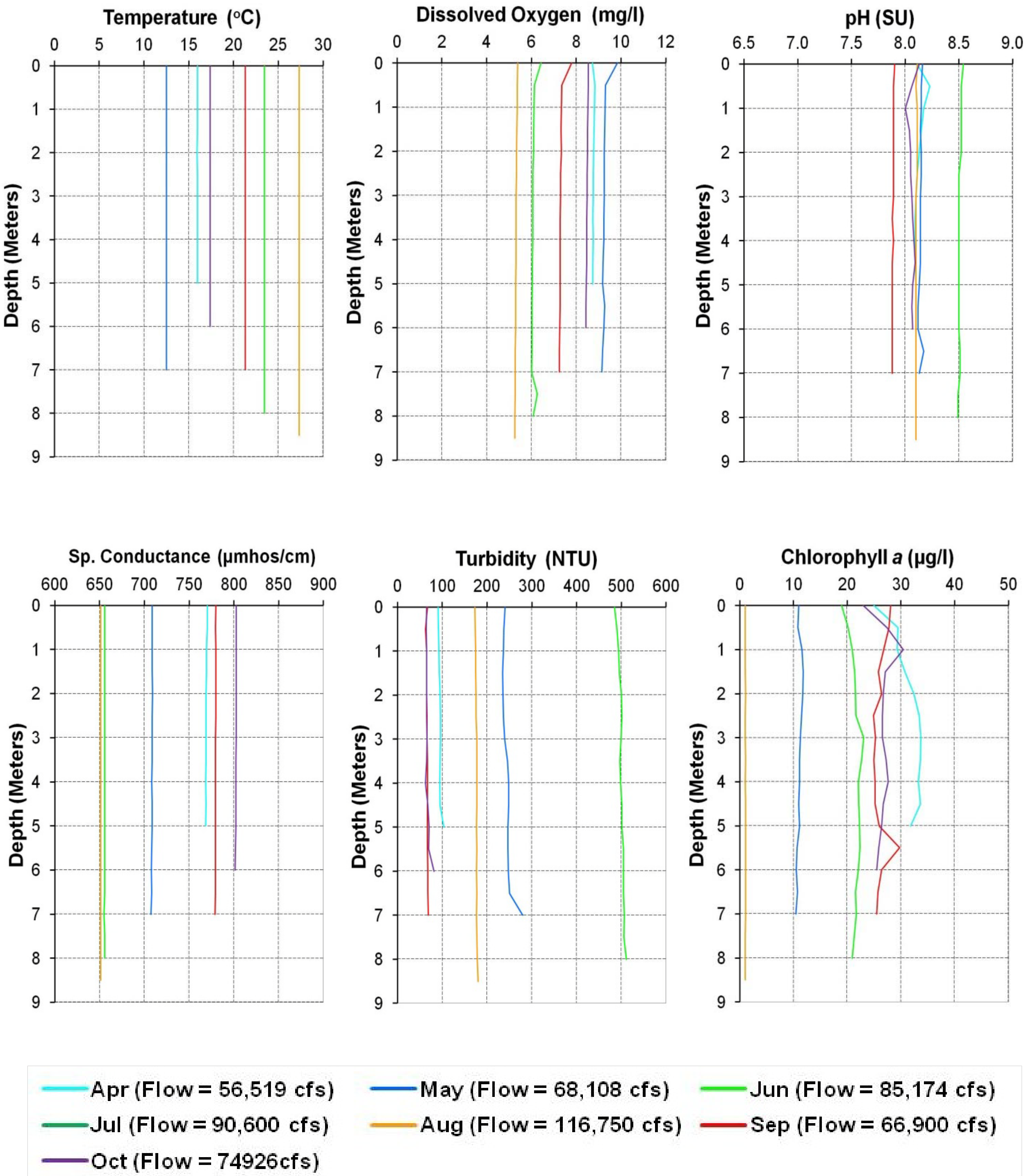


Plate 444. Water temperature, dissolved oxygen, pH, specific conductance, turbidity, and chlorophyll *a* depth profiles for the Missouri River compiled from data collected at RM498 (i.e., MORRR0498) during 2010.

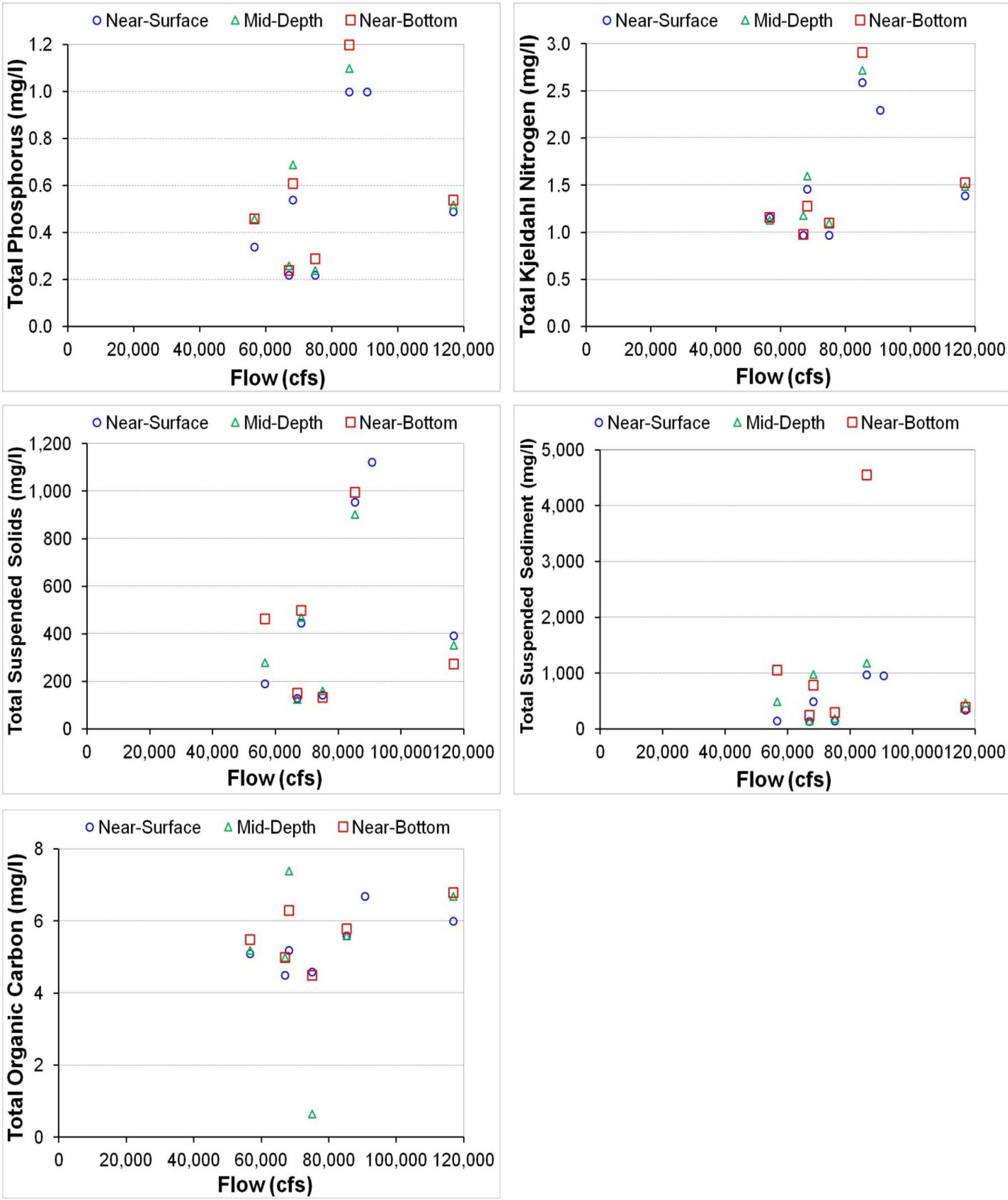


Plate 445. Comparison of flow and measured near-surface, mid-depth, and near-bottom concentrations of total phosphorus, total Kjeldahl nitrogen, total suspended solids, total suspended sediment, and total organic carbon in the Missouri River at RM498 (i.e., site MORRR0498) during 2010.

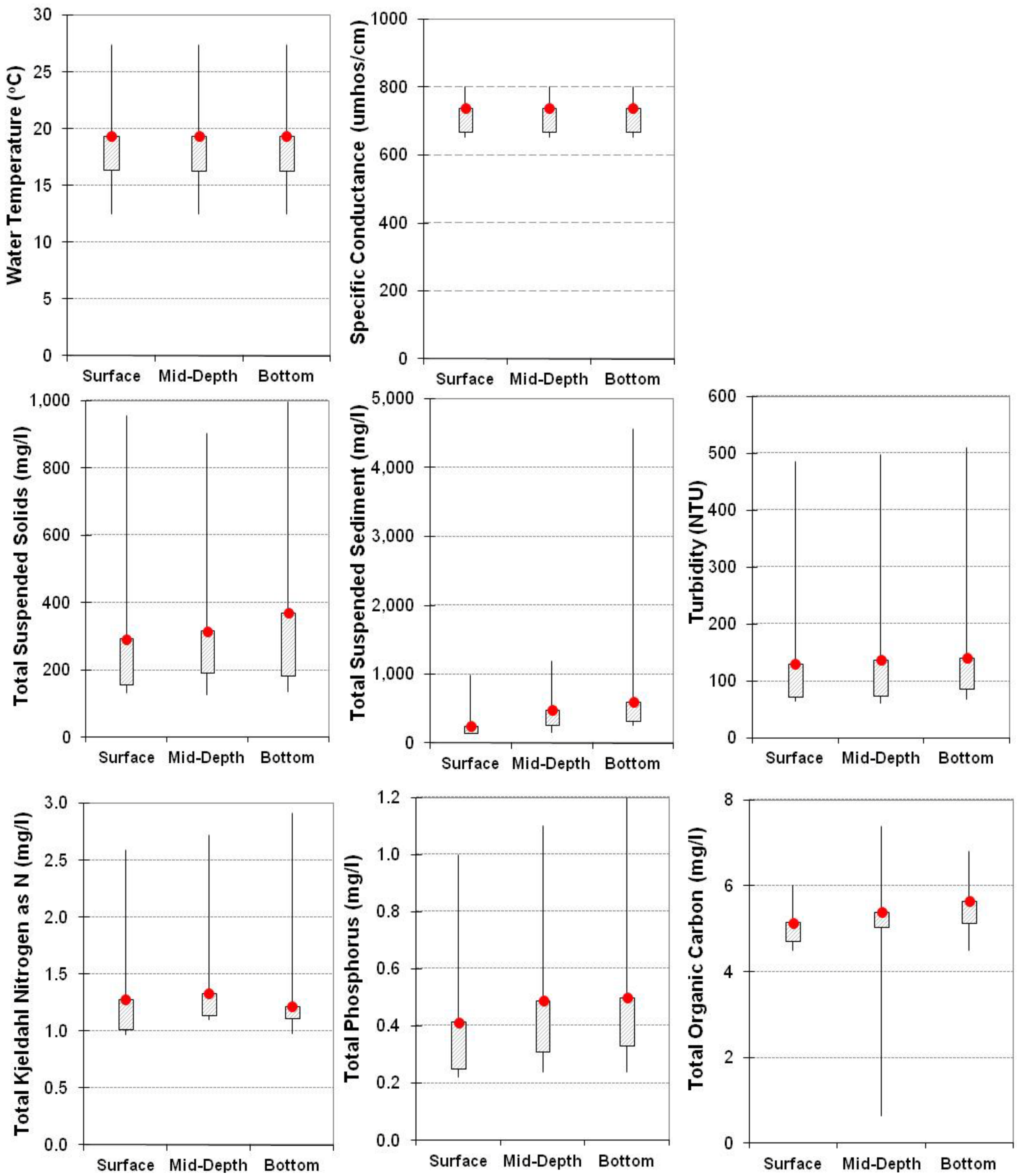
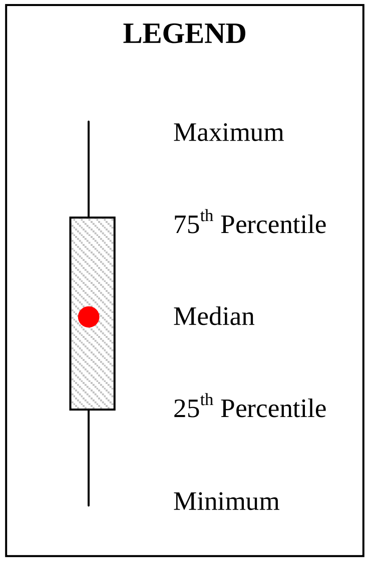


Plate 446. Box plots comparing paired surface, mid-depth, and bottom water temperature, specific conductance, total suspended solids, total suspended sediment, turbidity, total Kjeldahl nitrogen, total phosphorus, and total organic carbon measurements taken in the Missouri River at site MORRR0619 during 2010. (Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 447. Distribution plots (i.e., box plots) for selected parameters monitored at locations along the lower Missouri River from the Gavins Point Dam tailwaters to Rulo, Nebraska during the 5-year period of 2006 through 2010.



Note: Monitoring location refers to the River Mile (RM) along the Missouri River where the monitoring site was located.

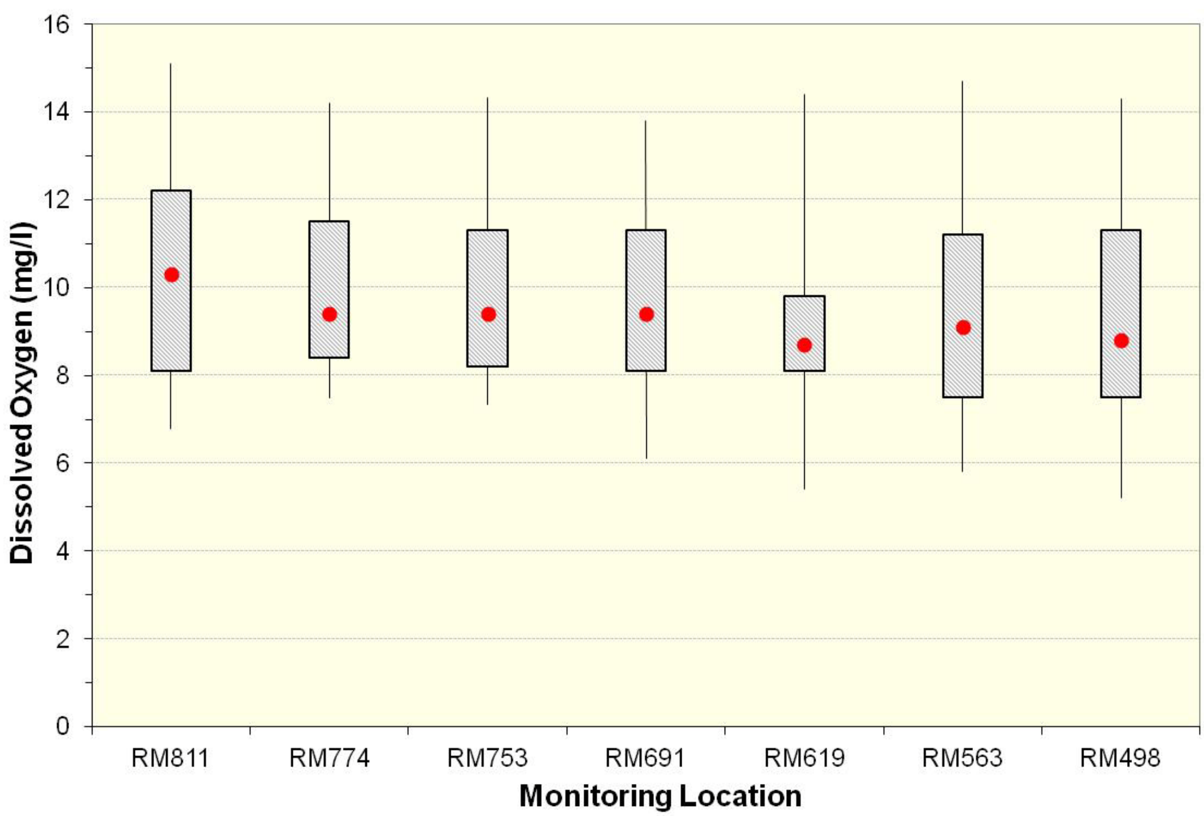
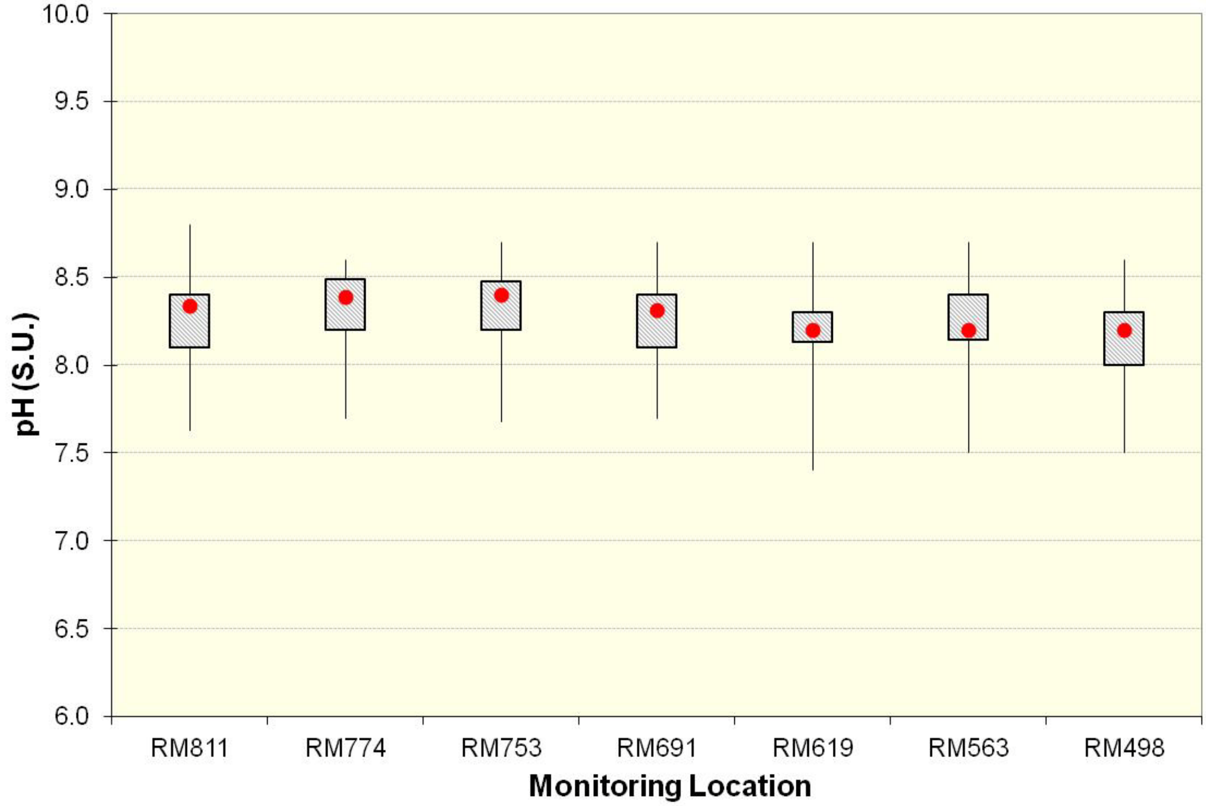


Plate 447. (Continued).



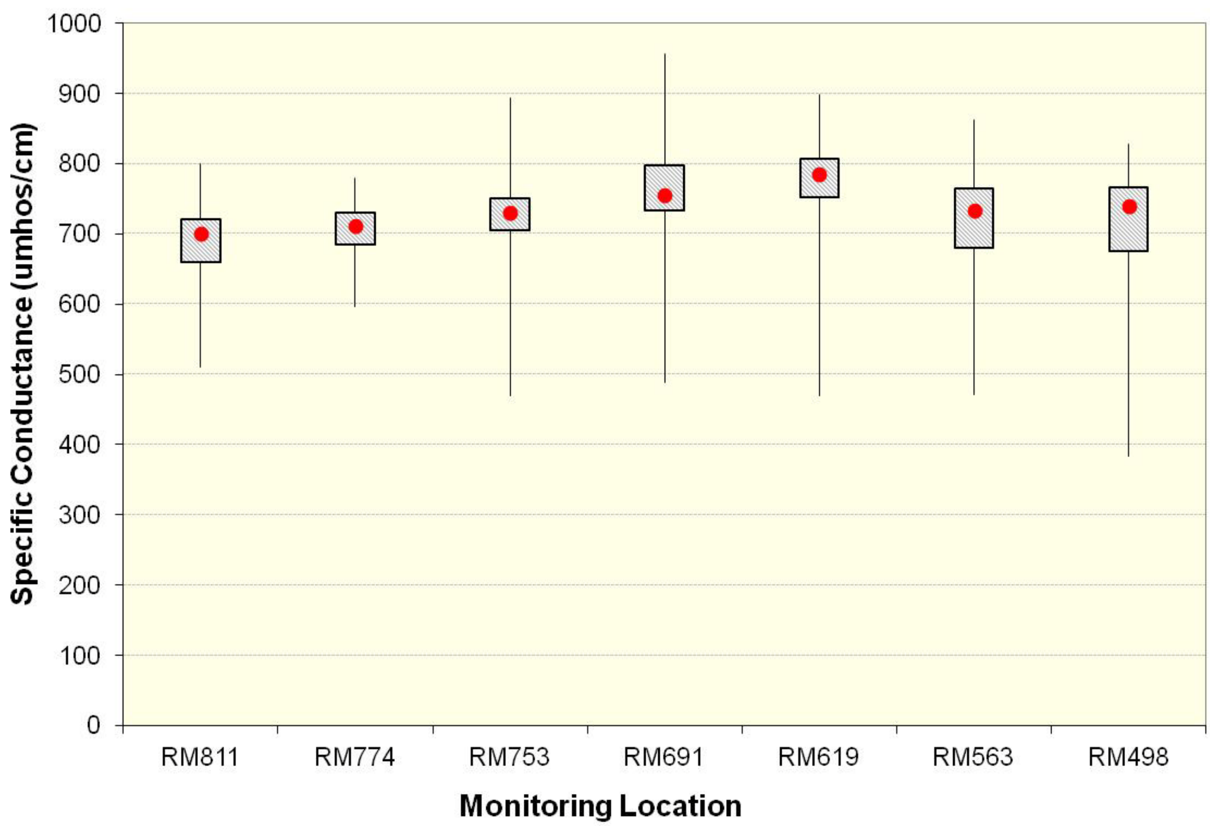
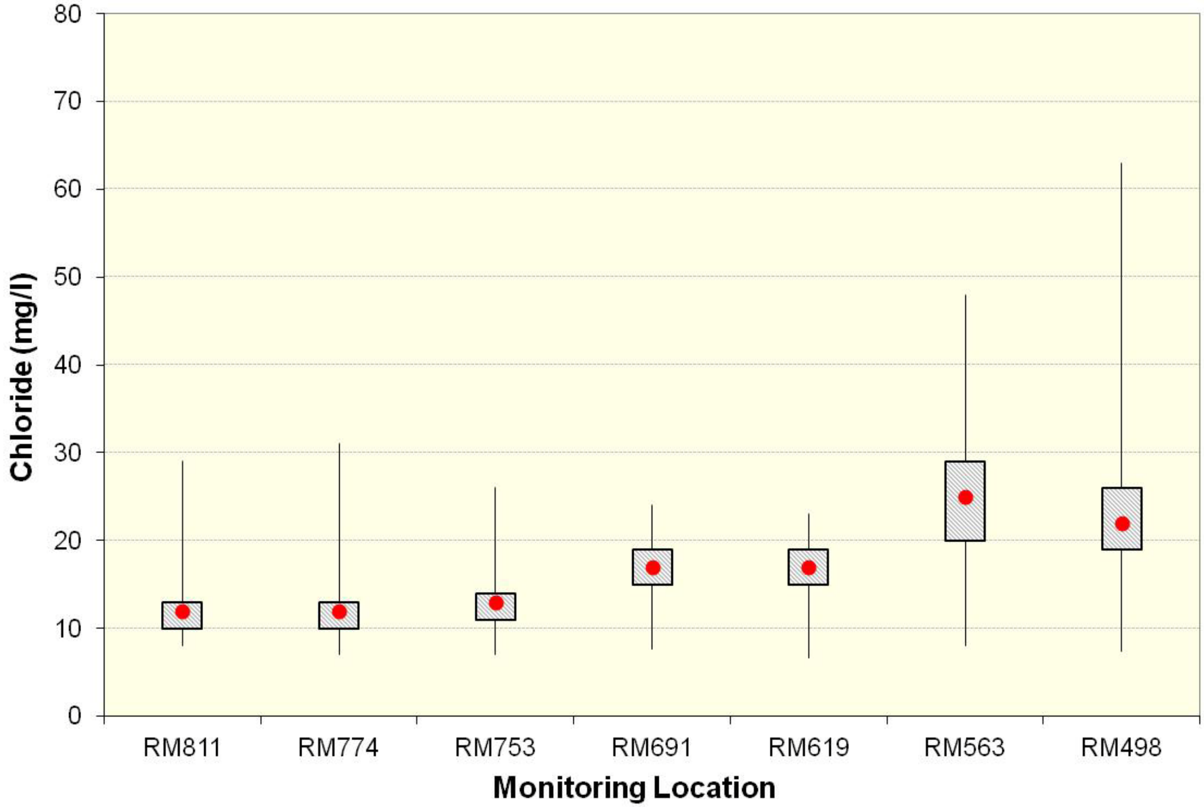


Plate 447. (Continued).



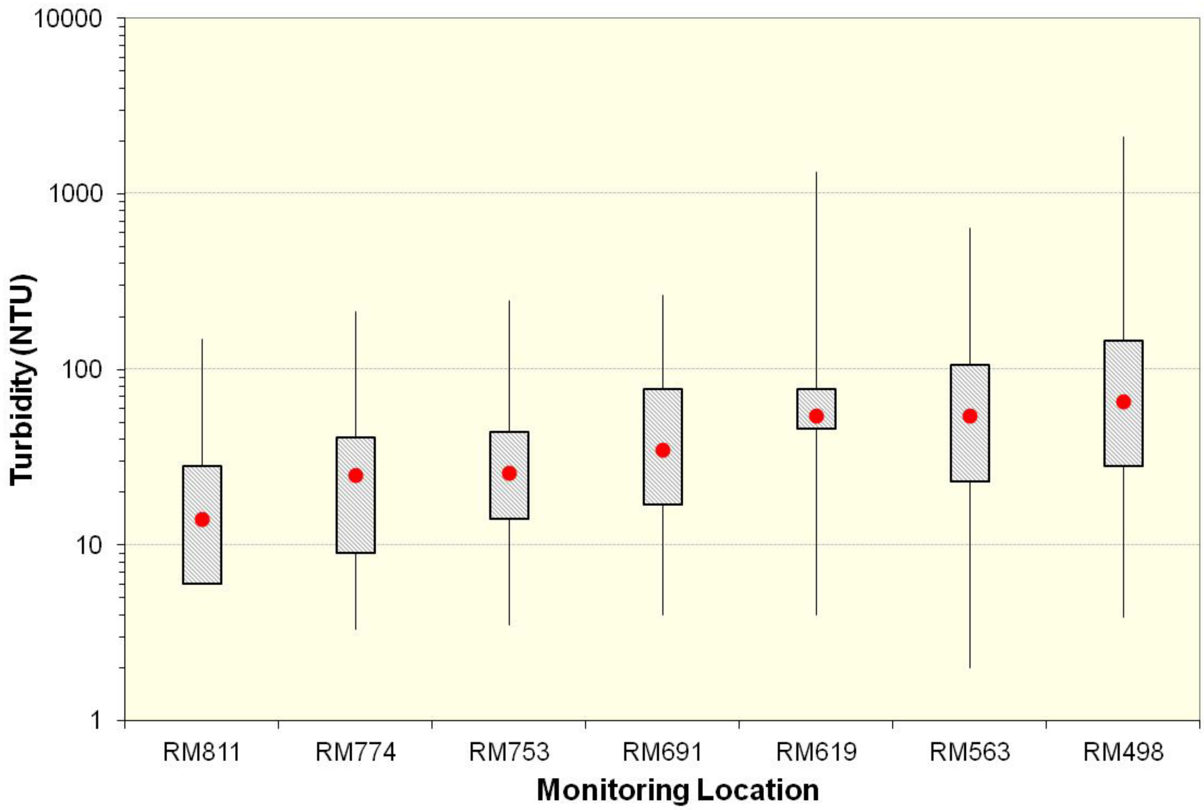
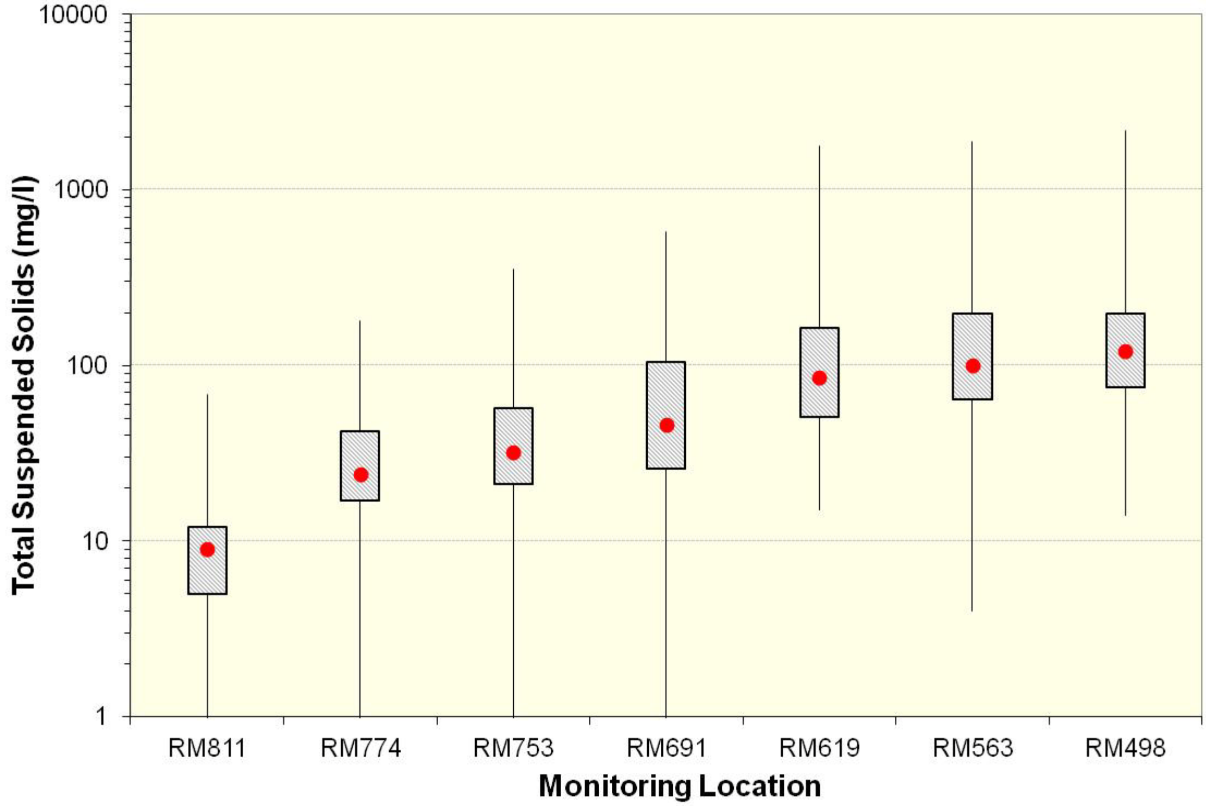


Plate 447. (Continued).



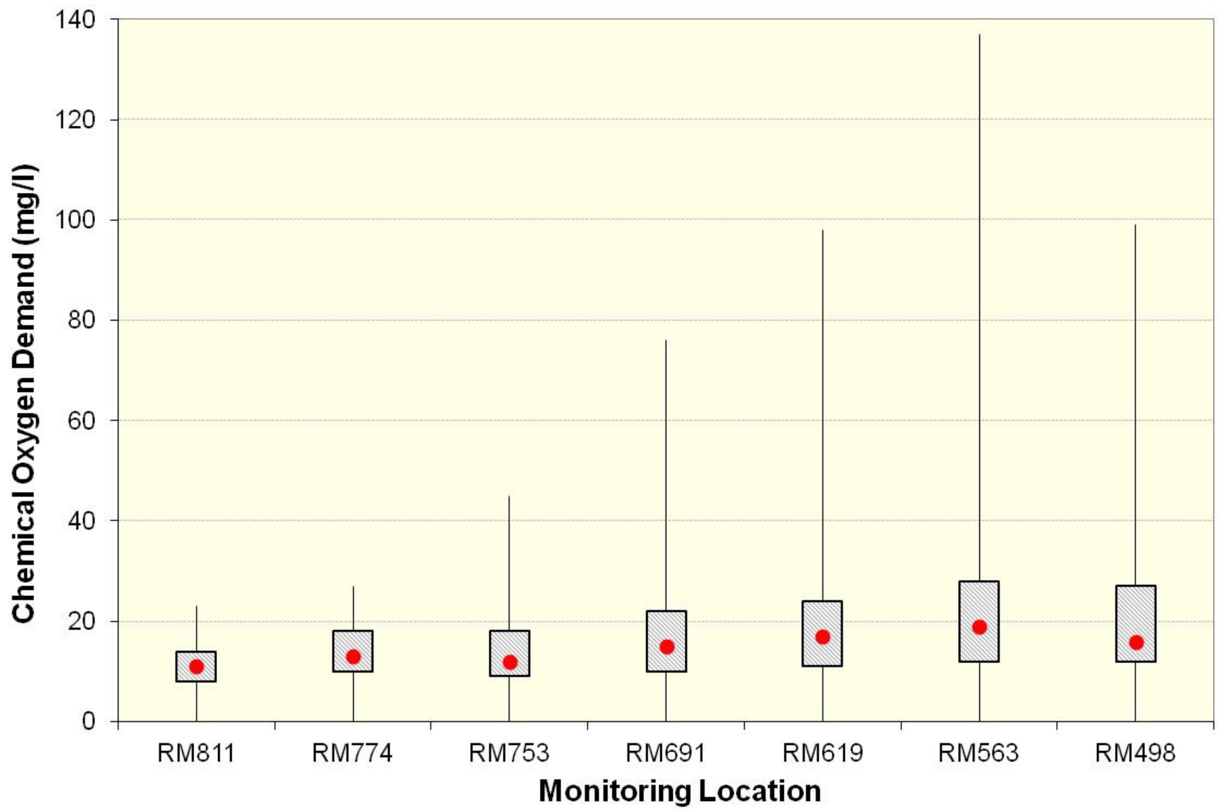
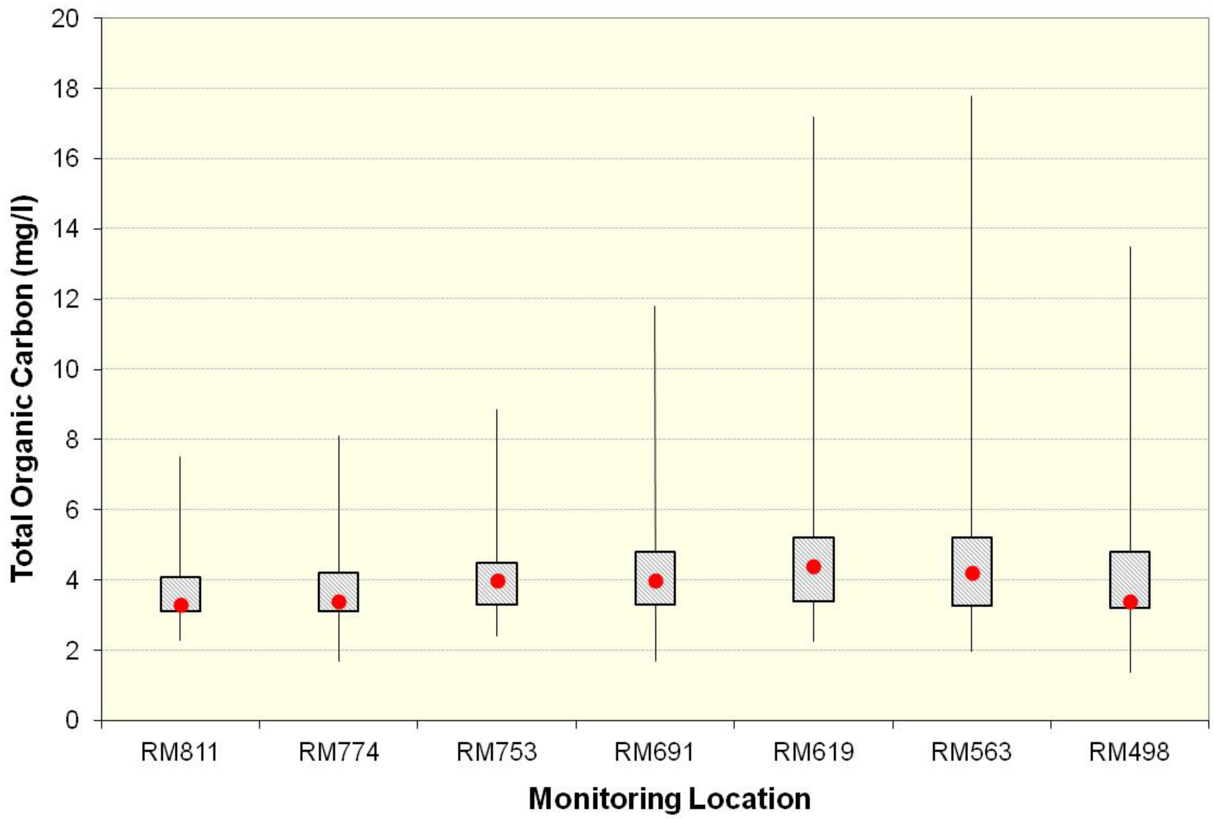


Plate 447. (Continued).



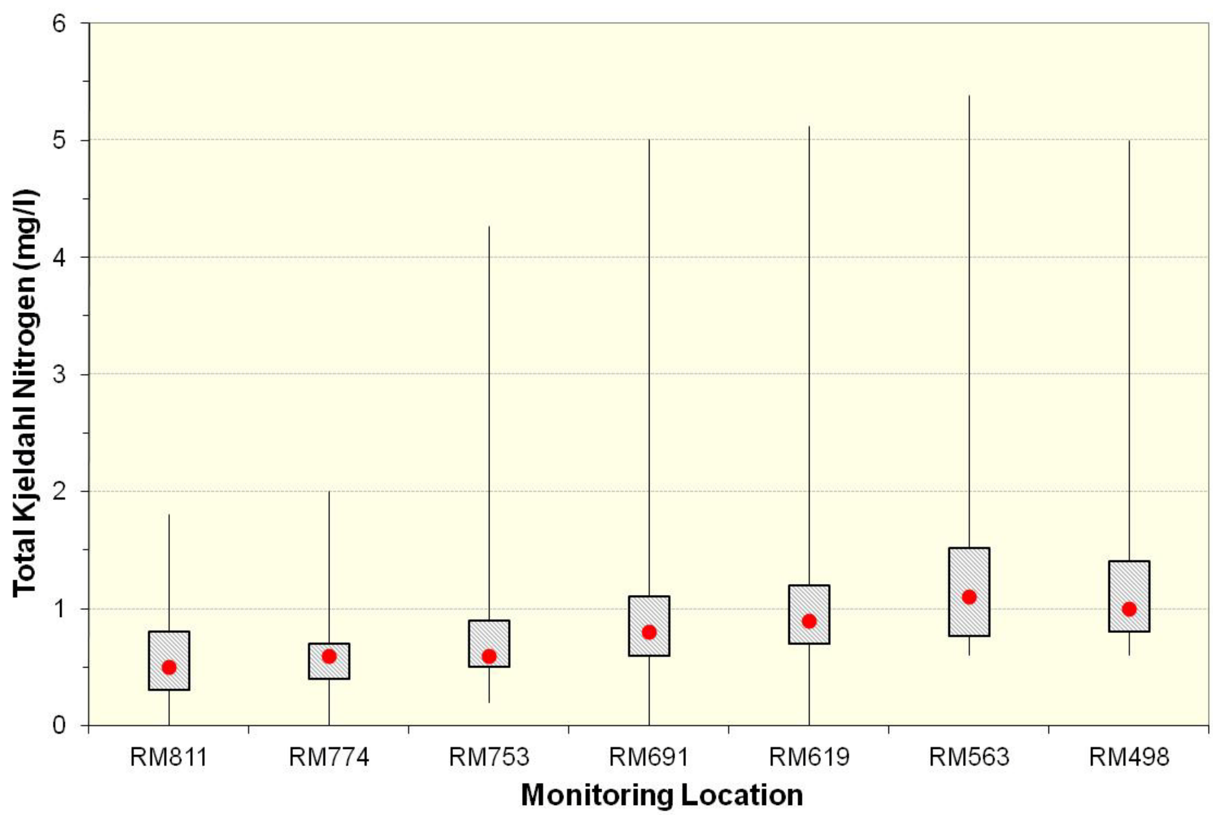
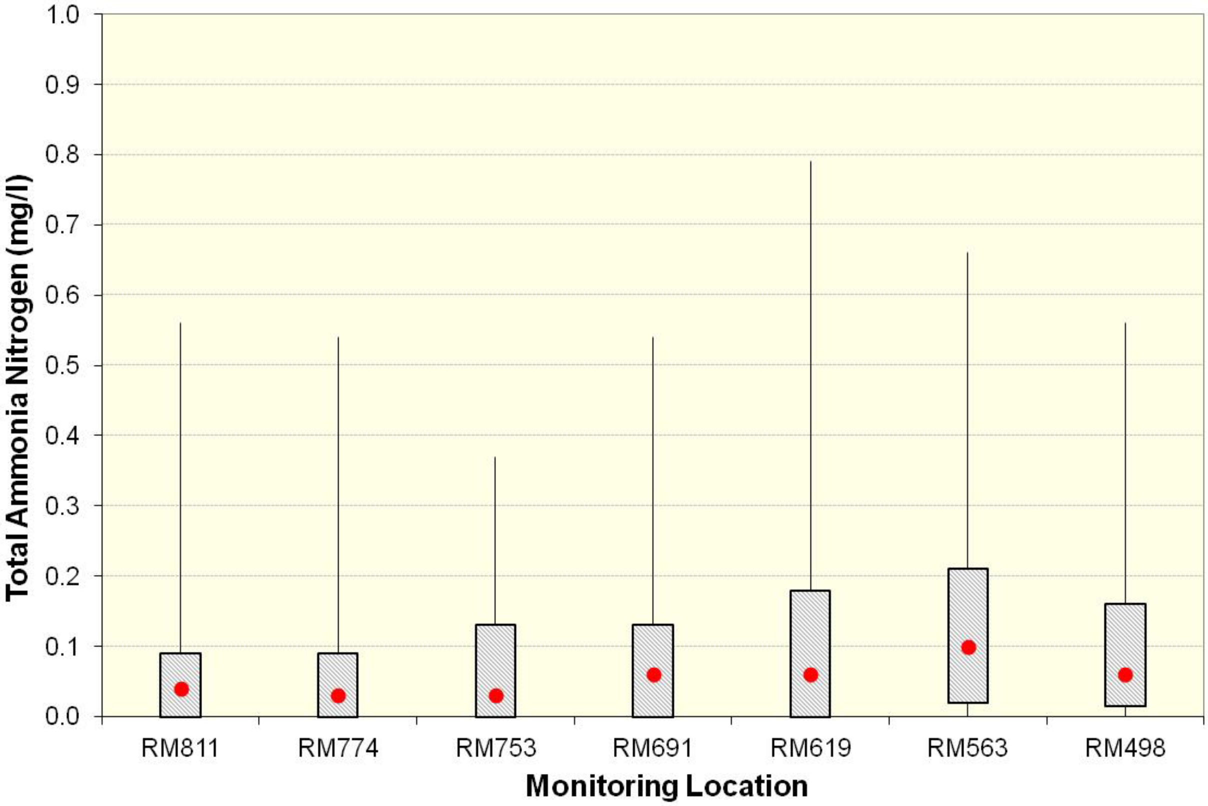


Plate 447. (Continued).



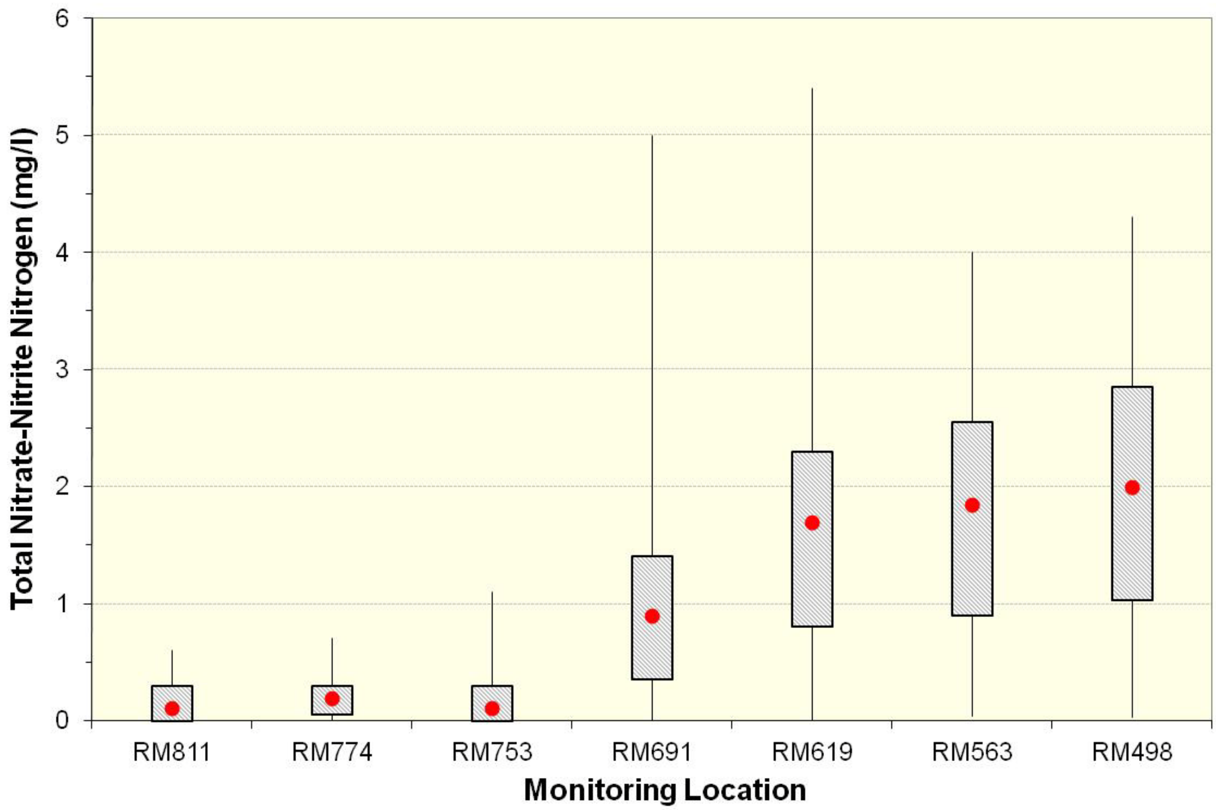
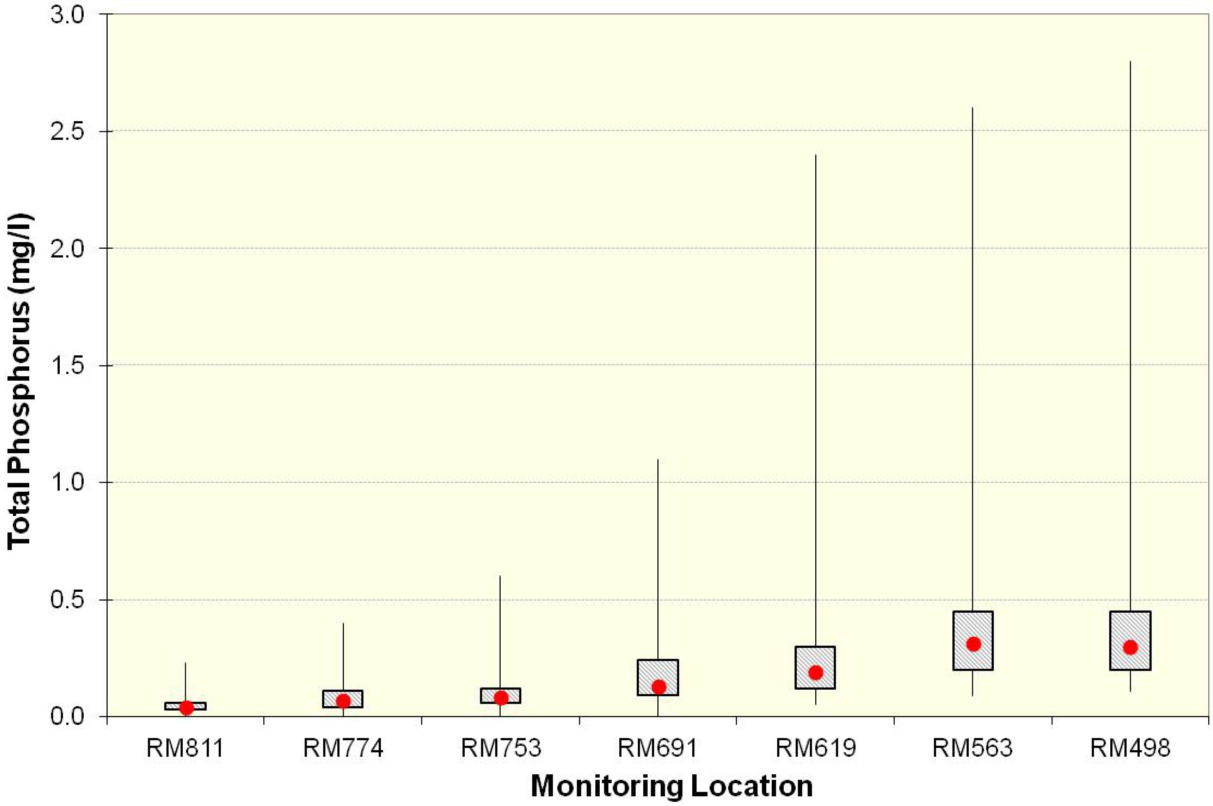


Plate 447. (Continued).



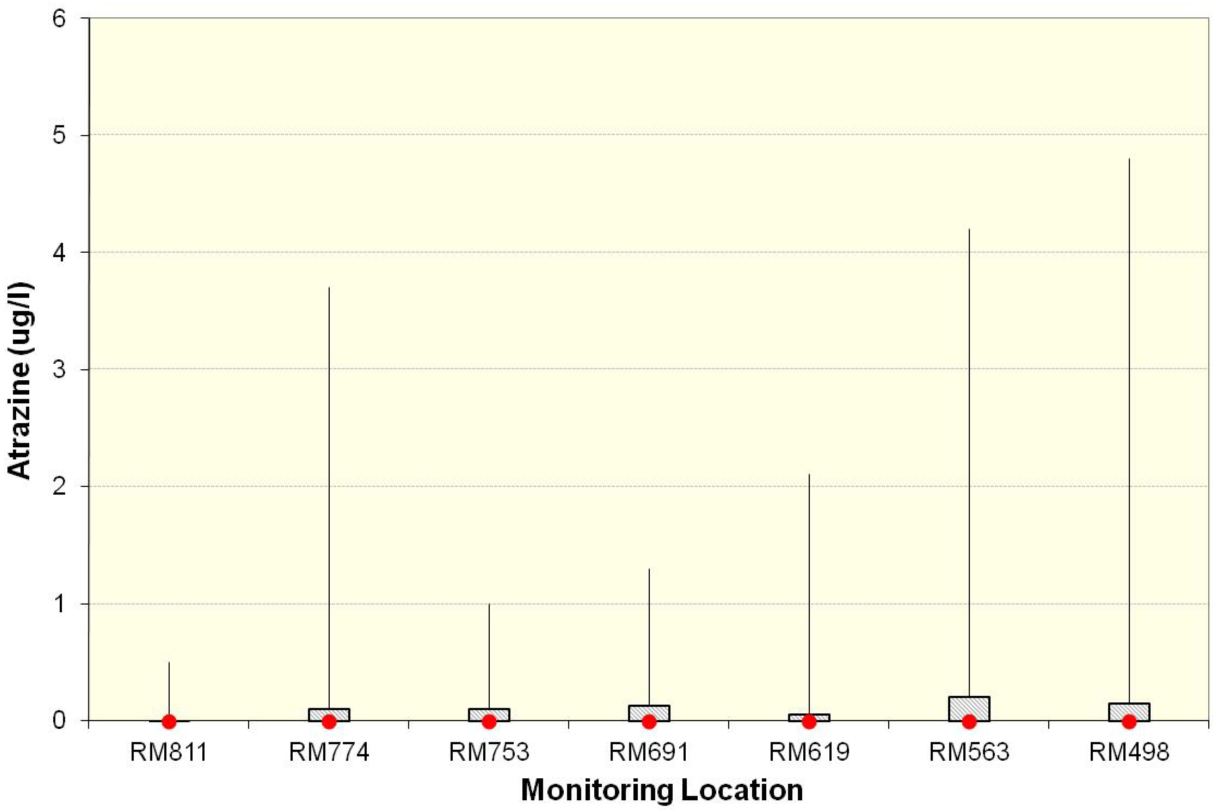


Plate 448. Mean daily water temperatures calculated for the lower Missouri River during 2010 at Gavins Point Dam; Sioux City, IA; and St. Joseph, MO.

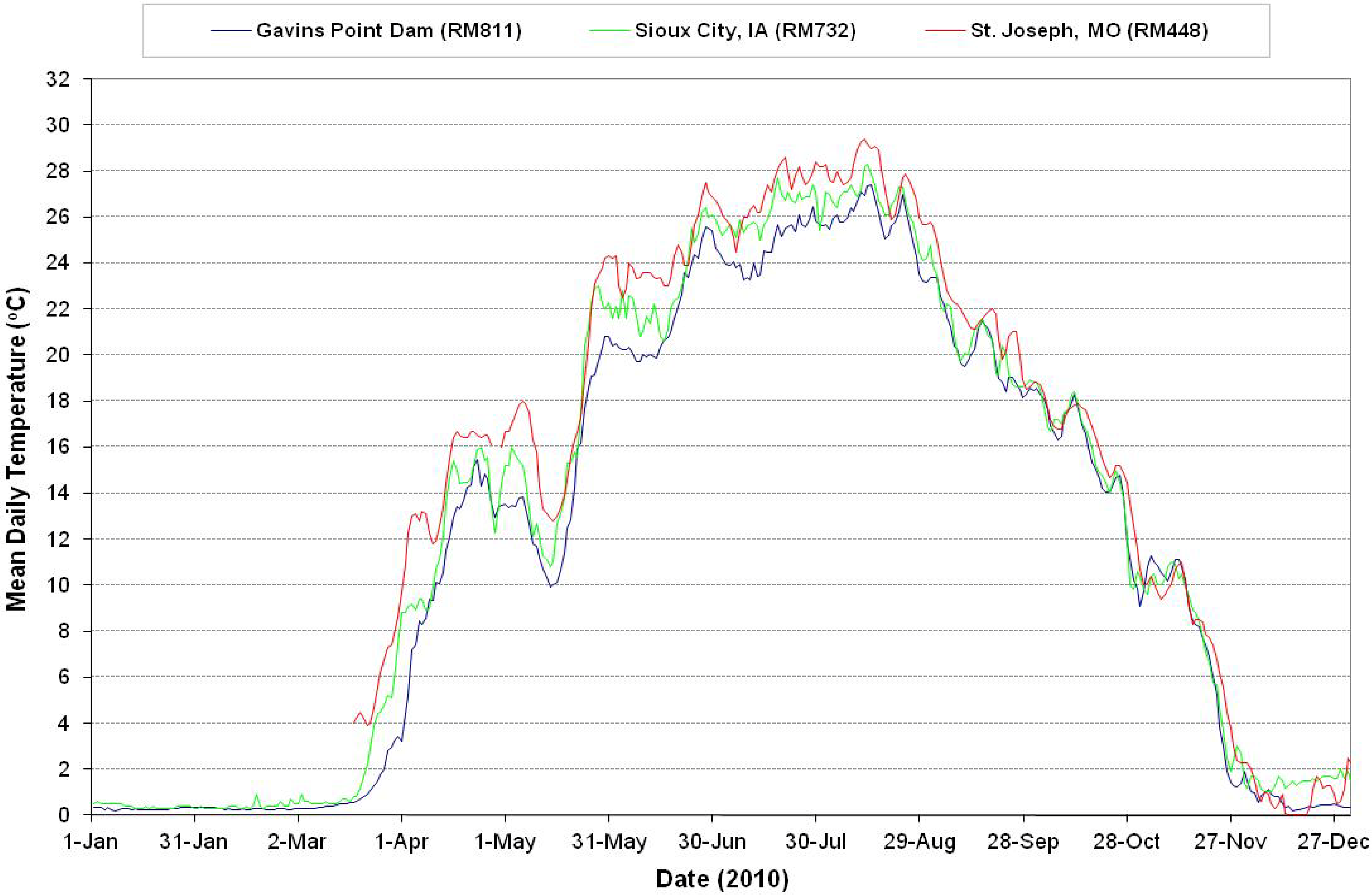


Plate 449. Summary of monthly (May through September) water quality conditions monitored in Lake Audubon (i.e., site AUDLKND1) during 2006 and 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation	1	9	1846.9	1846.9	1846.6	1847.0	-----	-----	-----
Water Temperature (°C)	0.1	152	17.6	18.3	9.6	25.5	29.4(1,2)	0	0%
Dissolved Oxygen (mg/l)	0.1	152	8.5	8.6	1.7	10.6	5.0(1,3)	5	3%
Dissolved Oxygen (% Sat.)	0.1	152	91.5	95.0	19.1	104.3	-----	-----	-----
Specific Conductance (umhos/cm)	1	150	917	932	803	969	-----	-----	-----
pH (S.U.)	0.1	152	8.5	8.5	7.7	8.8	6.5(1,3), 9.0(1,2)	0	0%
Oxidation-Reduction Potential (mV)	1	152	358	341	271	477	-----	-----	-----
Secchi Depth (in)	1	9	89	65	48	192	-----	-----	-----
Alkalinity, Total (mg/l)	7	18	207	209	170	220	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	18	4.7	4.8	3.4	6.0	-----	-----	-----
Chloride (mg/l)	1	18	14	15	11	16	-----	-----	-----
Chlorophyll *a* (ug/l) - Field Probe	1	69	-----	6	n.d.	10	-----	-----	-----
Chlorophyll *a* (ug/l) - Lab Determined	1	9	-----	3	n.d.	7	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	18	699	672	590	862	-----	-----	-----
Hardness, Total (mg/l)	0.4	3	270	272	264	275	-----	-----	-----
Iron, Dissolved (ug/l)	40	14	-----	n.d.	n.d.	40	-----	-----	-----
Iron, Total (ug/l)	40	14	206	195	80	383	-----	-----	-----
Manganese, Dissolved (ug/l)	2	14	-----	n.d.	n.d.	4	-----	-----	-----
Manganese, Total (ug/l)	2	14	11	10	n.d.	24	-----	-----	-----
Nitrogen, Total Ammonia (mg/l)	0.02	18	-----	0.04	n.d.	0.13	3.2 (1,2,4), 1.0 (1,4,5)	0	0%
Nitrogen, Total Kjeldahl (mg/l)	0.1	18	0.5	0.4	n.d.	1.3	-----	-----	-----
Nitrogen, Total Nitrate-Nitrite (mg/l)	0.02	18	-----	n.d.	n.d.	0.10	-----	-----	-----
Nitrogen, Total (mg/l)	0.1	18	0.5	0.5	n.d.	1.3	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	18	-----	n.d.	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	18	-----	0.03	n.d.	0.35	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	18	-----	n.d.	n.d.	0.02	-----	-----	-----
Sulfate (mg/l)	1	18	294	276	266	330	-----	-----	-----
Suspended Solids, Total (mg/l)	4	18	-----	n.d.	n.d.	8	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	1	0.7	0.7	0.7	0.7	5.6(8)	0	0%
Arsenic, Dissolved (ug/l)	1	2	3	3	2	3	340(6), 150(7), 10(8)	0	0%
Beryllium, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	4(8)	0	0%
Cadmium, Dissolved (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	5.9(6), 0.57(7), 5(8)	0	0%
Chromium, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	4,092(6), 196(7), 100(8)	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	35.9(6), 22(7), 1,000(8)	0	0%
Lead, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	292(6), 11(7), 15(8)	0	0%
Nickel, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	1,094(6), 122(7), 100(8)	0	0%
Selenium, Total (ug/l)	1	1	-----	n.d.	n.d.	n.d.	20(6), 5(7), 50(8)	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	14.7(6)	0	0%
Zinc, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	280(6,7), 7,400(8)	0	0%
Pesticide Scan (ug/l)(D)	0.05	2	-----	n.d.	n.d.	n.d.	-----	-----	-----
Microcystin	0.2	9	-----	n.d.	n.d.	0.2	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for Class 2 lakes.
- (2) Daily maximum criterion (monitoring results directly comparable to criterion).
- (3) Daily minimum criterion (monitoring results directly comparable to criterion).
- (4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (5) 30-day average criterion (monitoring results not directly comparable to criterion).
- (6) Acute criterion for aquatic life.
- (7) Chronic criterion for aquatic life.
- (8) Human health criterion for surface waters.

Note: Some of North Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

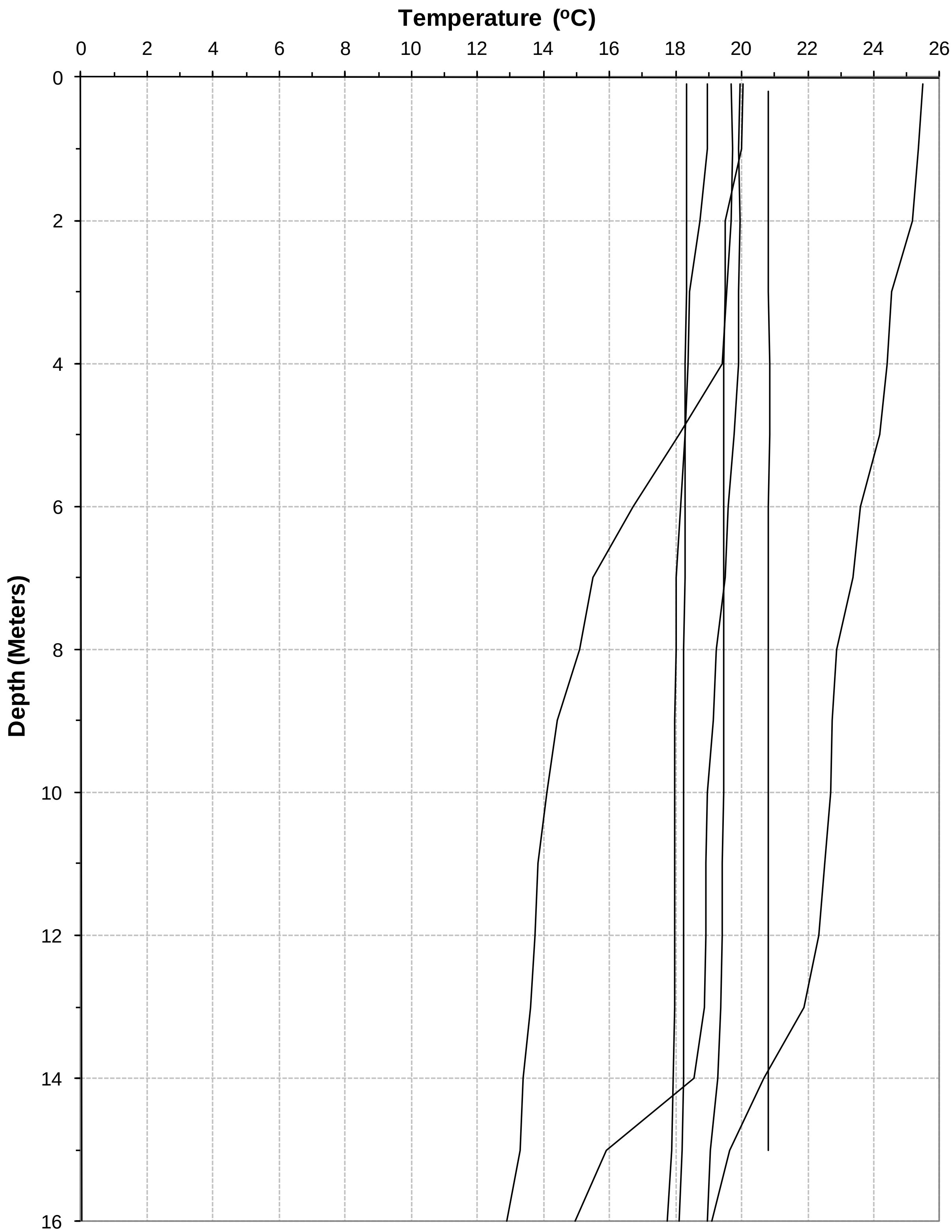


Plate 450. Temperature depth profiles for Lake Audubon generated from data collected at the near-dam, deepwater ambient monitoring site during the summer months of 2006 and 2009.

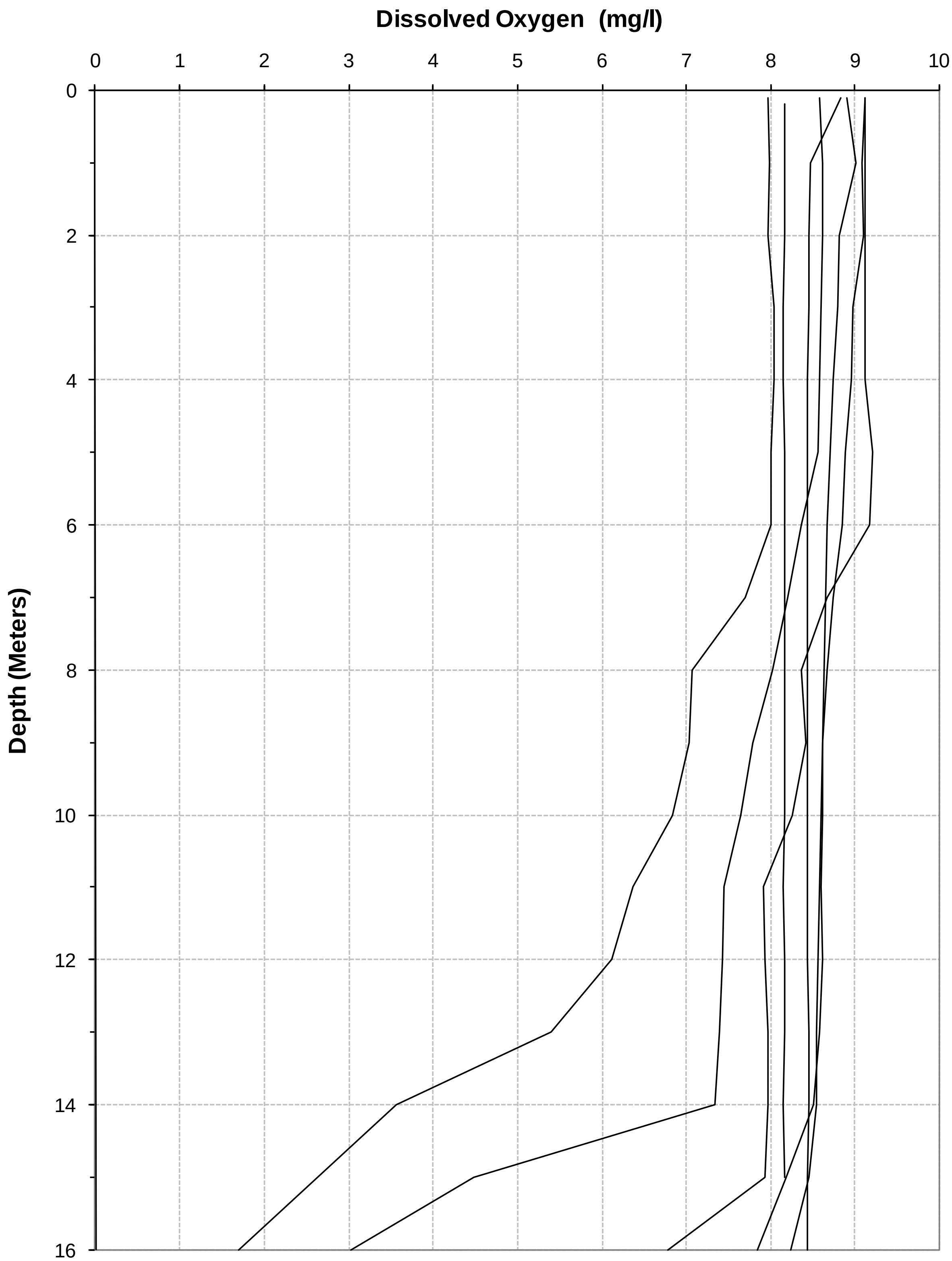


Plate 451. Dissolved oxygen depth profiles for Lake Audubon generated from data collected at the near-dam, deepwater ambient monitoring site during the summer months of 2006 and 2009.

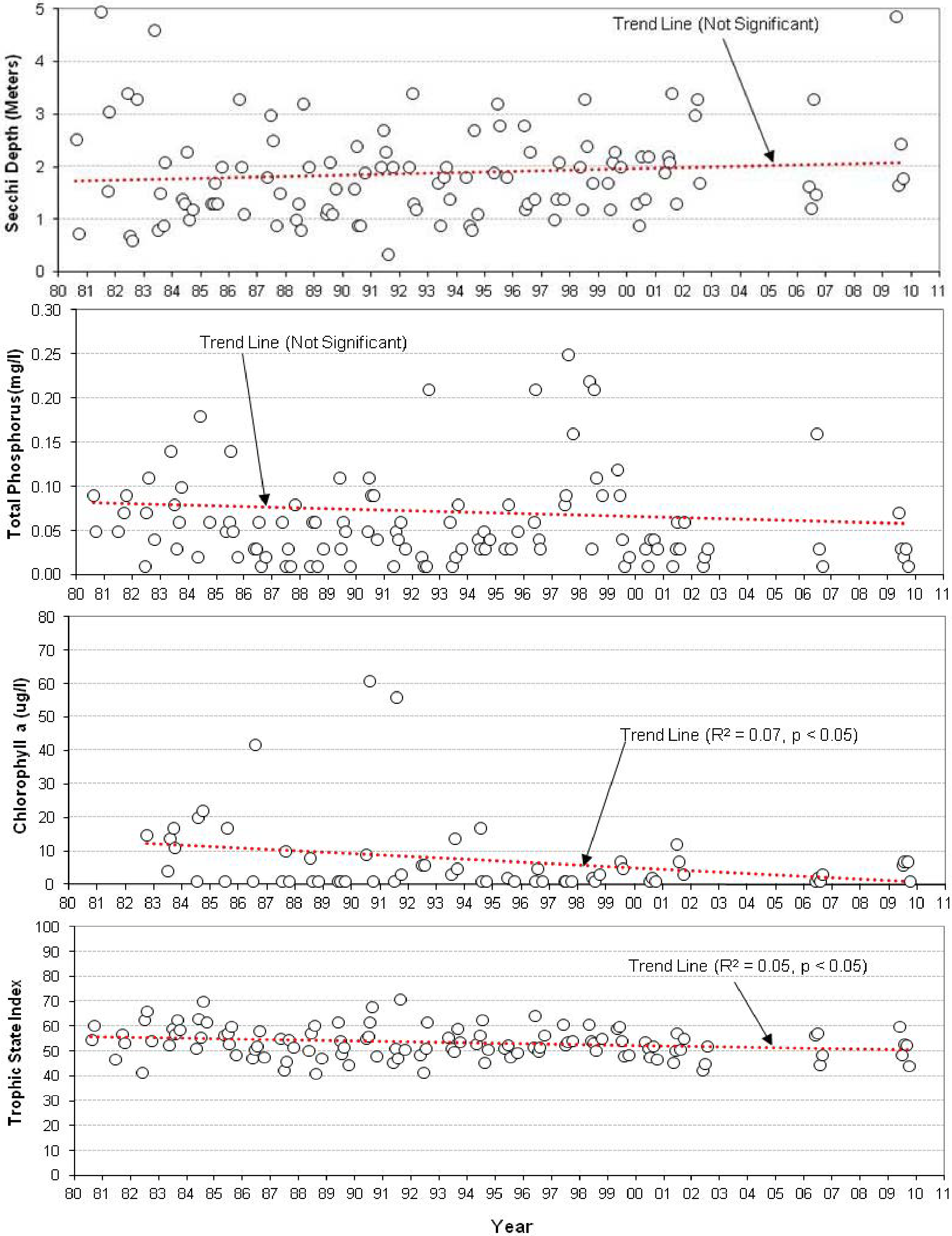


Plate 452. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Lake Audubon at the near-dam, ambient site over the 30-year period of 1980 through 2009.

Plate 453. Summary of monthly (June through September) water quality conditions monitored in Lake Pocasse (i.e., site POCLKND1) during 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation	1	4	1616.9	1617.0	1616.6	1617.0	-----	-----	-----
Water Temperature (°C)	0.1	17	20.6	19.7	19.1	22.8	27(1,4)	0	0%
Dissolved Oxygen (mg/l)	0.1	17	8.5	8.6	8.2	8.7	5.0(1,5)	0	0%
Dissolved Oxygen (% Sat.)	0.1	17	97.9	96.7	93.0	104.5	-----	-----	-----
Specific Conductance (umhos/cm)	1	17	604	568	502	717	-----	-----	-----
pH (S.U.)	0.1	17	8.5	8.6	8.2	8.9	6.5(1,2,5), 9.0(1,2)	0	0%
Oxidation-Reduction Potential (mV)	1	17	385	382	321	454	-----	-----	-----
Secchi Depth (in)	1	4	24	23	17	34	-----	-----	-----
Alkalinity, Total (mg/l)	7	6	206	212	152	241	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	6	13.3	15.9	1.1	20.9	-----	-----	-----
Chloride (mg/l)	1	6	16	17	12	18	-----	-----	-----
Chlorophyll *a* (ug/l) - Field Probe	1	17	77	83	12	164	-----	-----	-----
Chlorophyll *a* (ug/l) - Lab Determined	1	4	70	75	12	118	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	6	463	485	366	524	-----	-----	-----
Hardness, Total (mg/l)	0.4	1	213	213	213	213	-----	-----	-----
Iron, Dissolved (ug/l)	40	2	15	15	10	20	-----	-----	-----
Iron, Total (ug/l)	40	2	460	460	340	580	-----	-----	-----
Manganese, Dissolved (ug/l)	2	2	575	575	540	610	-----	-----	-----
Manganese, Total (ug/l)	2	2	605	605	550	660	-----	-----	-----
Nitrogen, Total Ammonia (mg/l)	0.02	6	0.10	0.11	0.03	0.13	2.7 (1,2,4), 0.61 (1,4,5)	0	0%
Nitrogen, Total Kjeldahl (mg/l)	0.1	6	2.4	2.2	1.6	3.2	-----	-----	-----
Nitrogen, Total Nitrate-Nitrite (mg/l)	0.02	6	0.06	0.04	n.d.	0.20	-----	-----	-----
Nitrogen, Total (mg/l)	0.1	6	2.4	2.2	1.8	3.2	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	6	1.25	1.24	1.00	1.48	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	6	1.32	1.32	1.00	1.60	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	6	1.07	1.10	0.80	1.30	-----	-----	-----
Sulfate (mg/l)	1	6	105	109	84	115	-----	-----	-----
Suspended Solids, Total (mg/l)	4	6	15	16	4	24	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	1	3.8	3.8	3.8	3.8	5.6(8)	0	0%
Arsenic, Dissolved (ug/l)	1	1	12	12	12	12	340(6), 150(7)	0	0%
Beryllium, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	4(8)	0	0%
Cadmium, Dissolved (ug/l)	0.2	1	-----	n.d.	n.d.	n.d.	4.2(6), 0.42(7)	0	0%
Chromium, Dissolved (ug/l)	10	1	-----	n.d.	n.d.	n.d.	1,058(6), 138(7)	0	0%
Copper, Dissolved (ug/l)	2	1	-----	n.d.	n.d.	n.d.	27(6), 17(7)	0	0%
Lead, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	146(6), 5.7(7)	0	0%
Nickel, Dissolved (ug/l)	10	1	-----	n.d.	n.d.	n.d.	888(6), 99(7)	0	0%
Selenium, Total (ug/l)	1	1	1	1	1	1	4.6(7), 170(8)	0	0%
Silver, Dissolved (ug/l)	1	1	-----	n.d.	n.d.	n.d.	11(6)	0	0%
Thallium, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	-----	-----	-----
Zinc, Dissolved (ug/l)	10	1	-----	n.d.	n.d.	n.d.	22(6,7)	0	0%
Microcystin	0.2	4	-----	0.06	n.d.	0.14	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of warmwater permanent fish life propagation waters.
(2) Daily maximum criterion (monitoring results directly comparable to criterion).
(3) Daily minimum criterion (monitoring results directly comparable to criterion).
(4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(5) 30-day average criterion (monitoring results not directly comparable to criterion).
(6) Acute criterion for aquatic life.
(7) Chronic criterion for aquatic life.
(8) Human health criterion for surface waters.

Note: Some of South Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

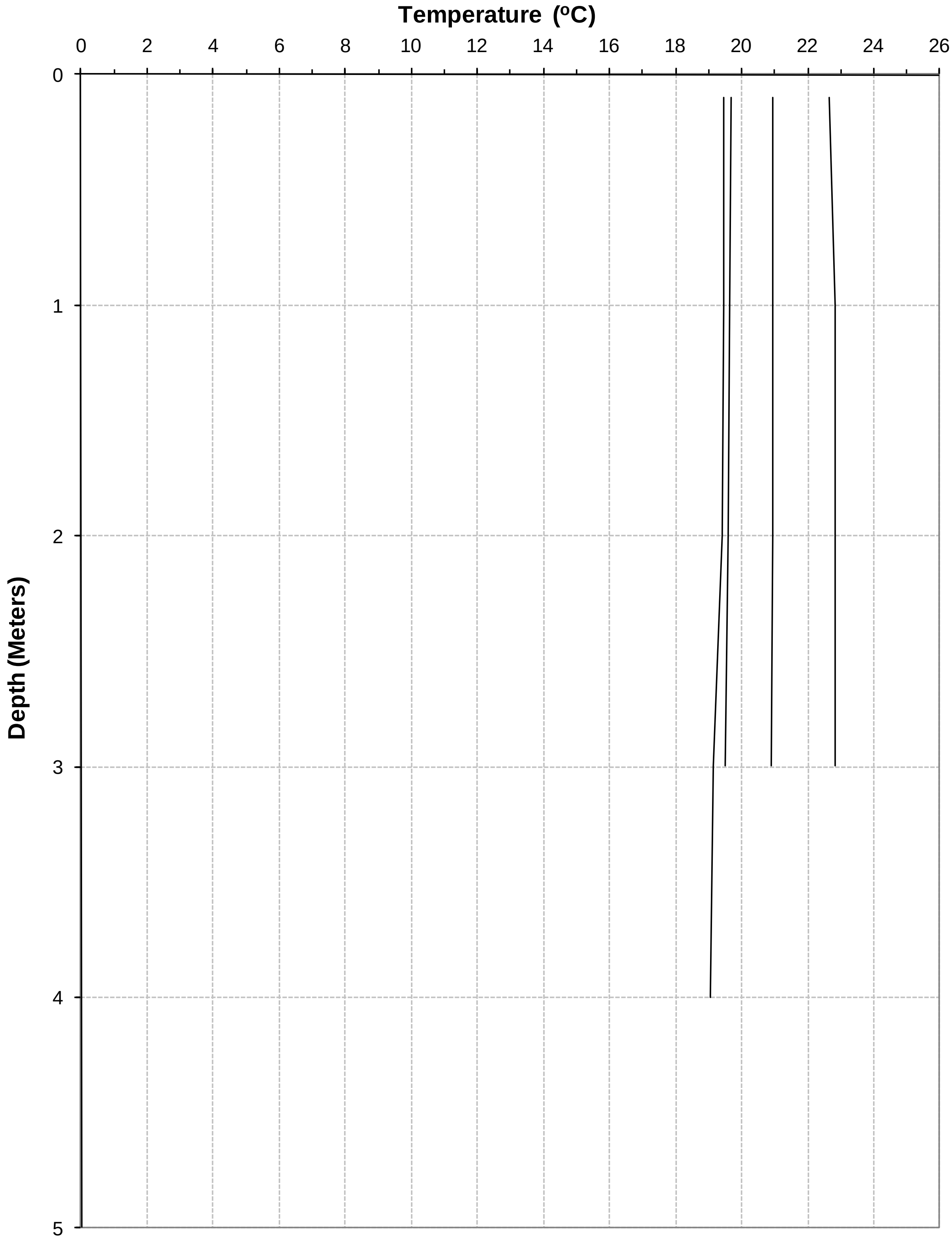


Plate 454. Temperature depth profiles for Lake Pocasse generated from data collected at the near-dam, deepwater ambient monitoring site during the summer months of 2009.

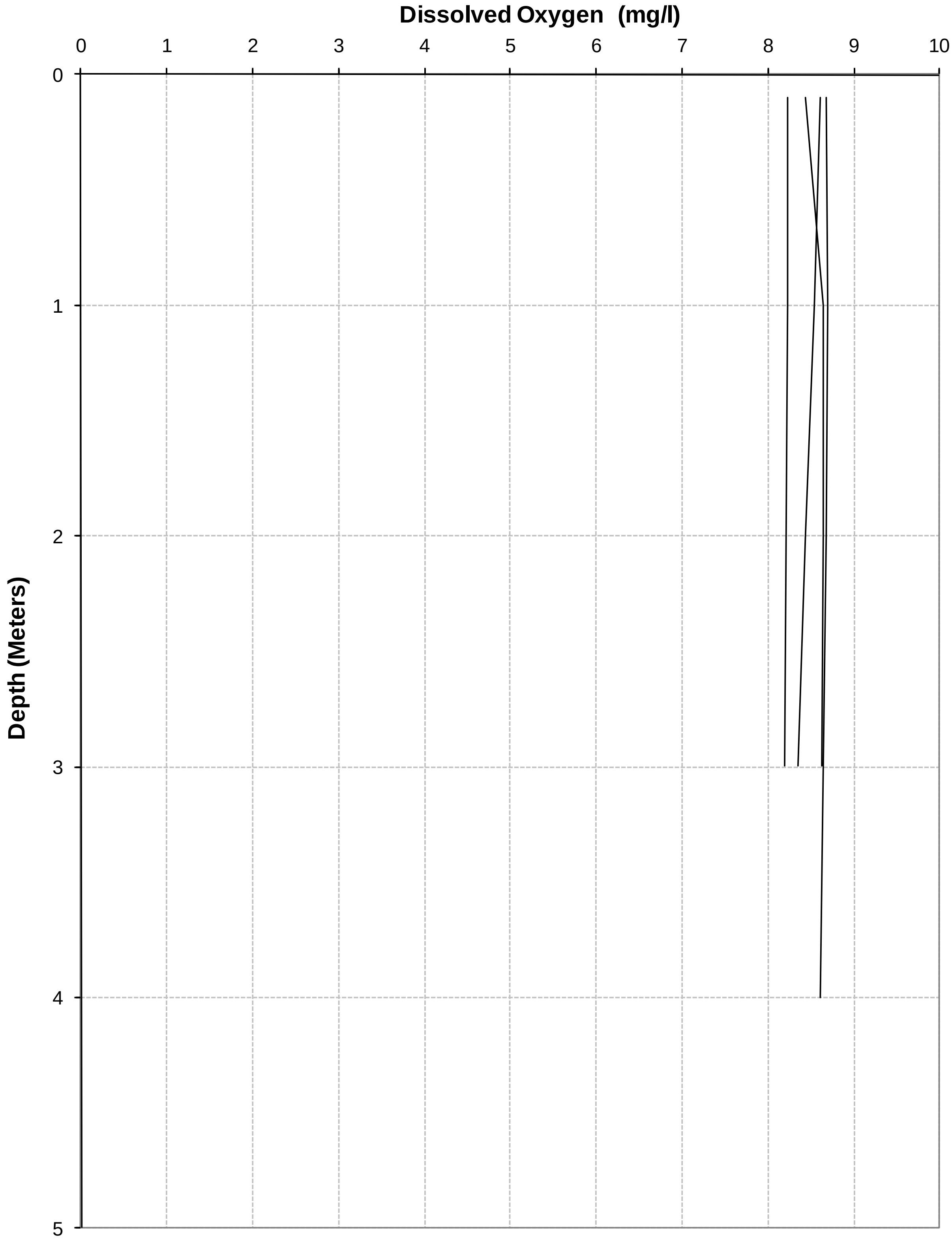


Plate 455. Dissolved oxygen depth profiles for Lake Pocasse generated from data collected at the near-dam, deepwater ambient monitoring site during the summer months of 2009.

Plate 456. Summary of monthly (May through September) water quality conditions monitored in Lake Yankton (i.e., site YAKLKND1) during 2006 and 2009.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation	1	8	1167.4	1167.5	1167.2	1167.7	-----	-----	-----
Water Temperature (°C)	0.1	58	19.2	18.5	14.2	26.1	27[1,2,5], 29[1,2,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	58	5.9	7.7	0.3	11.8	5[1,2,7]	22	38%
Dissolved Oxygen (% Sat.)	0.1	58	67.3	86.1	2.7	137.8	-----	-----	-----
Specific Conductance (umhos/cm)	1	58	1012	1025	874	1191	2,000[4]	0	0%
pH (S.U.)	0.1	58	7.8	7.8	7.2	8.7	6.5[1,3,6], 9.0[1,3,5]	0	0%
Oxidation-Reduction Potential (mV)	1	58	337	350	31	480	-----	-----	-----
Secchi Depth (in)	1	10	45	46	12	67	-----	-----	-----
Alkalinity, Total (mg/l)	7	20	184	191	140	220	-----	-----	-----
Carbon, Total Organic (mg/l)	0.05	20	3.5	3.1	1.1	15.9	-----	-----	-----
Chloride (mg/l)	1	20	14	14	12	17	-----	-----	-----
Chlorophyll *a* (ug/l) - Field Probe	1	31	16	14	3	70	-----	-----	-----
Chlorophyll *a* (ug/l) - Lab Determined	1	10	11	6	n.d.	54	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	20	735	736	680	790	-----	-----	-----
Hardness, Total (mg/l)	0.4	3	410	414	401	416	-----	-----	-----
Iron, Dissolved (ug/l)	40	16	-----	n.d.	n.d.	50	-----	-----	-----
Iron, Total (ug/l)	40	16	129	118	40	250	-----	-----	-----
Manganese, Dissolved (ug/l)	2	16	1,215	436	n.d.	6,820	-----	-----	-----
Manganese, Total (ug/l)	2	16	1,432	594	170	6,820	-----	-----	-----
Nitrogen, Total Ammonia (mg/l)	0.02	20	-----	0.07	n.d.	0.48	12.1[1,5,8], 2.4 [1,7,8]	0	0%
Nitrogen, Total Kjeldahl (mg/l)	0.1	20	0.7	0.7	0.3	1.1	-----	-----	-----
Nitrogen, Total Nitrate-Nitrite (mg/l)	0.02	20	-----	n.d.	n.d.	0.19	10[3,5], 100[4,5]	0	0%
Nitrogen, Total (mg/l)	0.1	20	0.7	0.8	0.3	1.1	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	20	-----	n.d.	n.d.	0.02	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	20	0.05	0.03	n.d.	0.22	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	20	-----	n.d.	n.d.	0.15	-----	-----	-----
Sulfate (mg/l)	1	18	377	374	338	420	-----	-----	-----
Suspended Solids, Total (mg/l)	4	20	-----	2	n.d.	12	158[1,5], 90[1,7]	0	0%
Antimony, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	88[9], 30[10], 6[11]	0	0%
Arsenic, Dissolved (ug/l)	1	1	2	2	2	2	340[9], 16.7[10], 10[11]	0	0%
Beryllium, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	130[9], 5.3[10], 4[11]	0	0%
Cadmium, Dissolved (ug/l)	0.2	3	-----	n.d.	n.d.	n.d.	25.4[9], 0.7[10], 5[11]	0	0%
Chromium, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	2,026[9], 263[10], 100[11]	0	0%
Copper, Dissolved (ug/l)	2	3	-----	n.d.	n.d.	n.d.	55.3[9], 32.3[10], 1,000[11]	0	0%
Lead, Dissolved (ug/l)	0.5	1	-----	n.d.	n.d.	n.d.	316[9], 12.3[10], 15[11]	0	0%
Nickel, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	1,668[9], 185[10], 100[11]	0	0%
Selenium, Total (ug/l)	1	1	1	1	1	1	20[4,9], 5[10], 50[11]	0	0%
Silver, Dissolved (ug/l)	1	3	-----	n.d.	n.d.	n.d.	45.7[9], 100[11]	0	0%
Zinc, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	422[9,10], 5,000[11]	0	0%
Microcystin	0.2	10	-----	n.d.	n.d.	n.d.	-----	-----	-----
Pesticide Scan (ug/l)[D]	0.05	2					-----	-----	-----
Atrazine (ug/l)			-----	17.8	n.d.	29.6	330[9], 12[10]	0, 1	0%, 50%
Chloropyrifos (ug/l)			-----	7.4	n.d.	14.7	0.083[9], 0.041[10]	1, 1	50%, 50%

n.d. = Not detected.

(A) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
(2) South Dakota's temperature criterion is 27°C and Nebraska's is 29°C. South Dakota's dissolved oxygen criterion is 6 mg/l and Nebraska's is 5 mg/l.
(3) Criteria for the protection of domestic water supply waters.
(4) Criteria for the protection of agricultural water supply waters.
(5) Daily maximum criterion (monitoring results directly comparable to criterion).
(6) Daily minimum criterion (monitoring results directly comparable to criterion).
(7) 30-day average criterion (monitoring results not directly comparable to criterion).
(8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(9) Acute (CMC) criterion for the protection of freshwater aquatic life.
(10) Chronic (CCC) criterion for the protection of freshwater aquatic life.
(11) Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, de-ethylatrazine, de-isopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate, and trifluralin. Individual pesticides were not detected unless listed under pesticide scan.

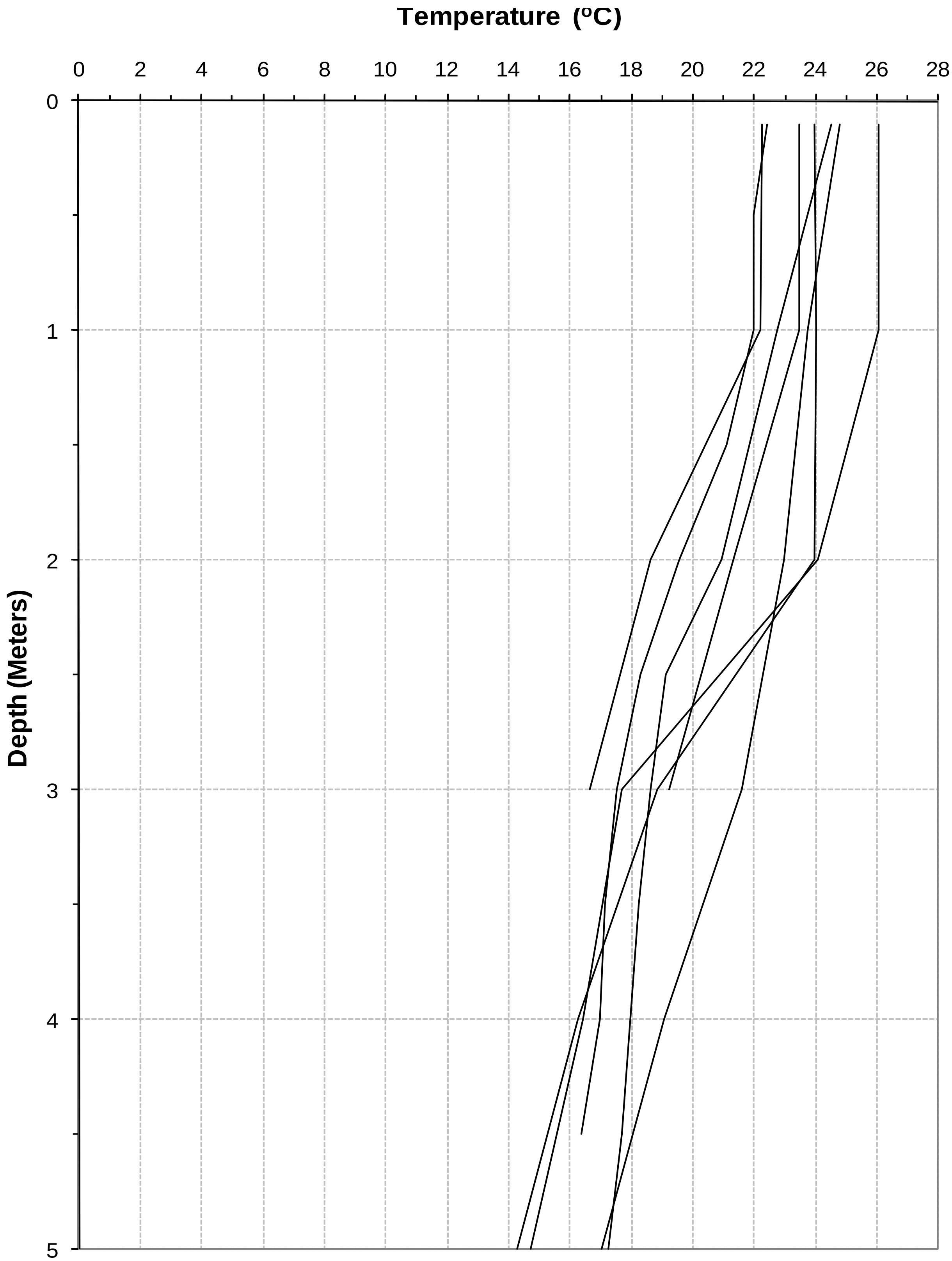


Plate 457. Temperature depth profiles for Lake Yankton generated from data collected at the deepwater ambient monitoring site during the summer months of 2006 and 2009.

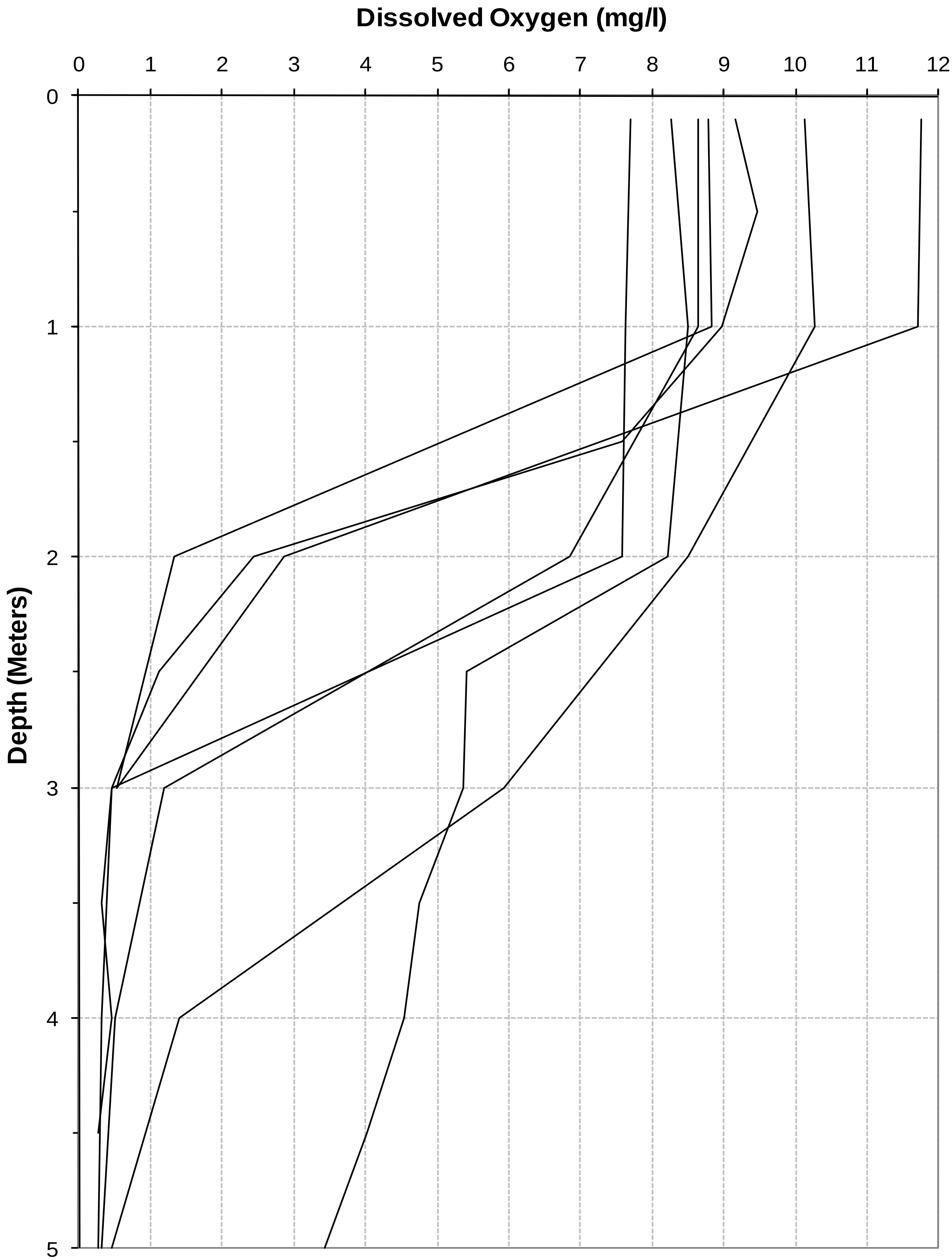


Plate 458. Dissolved oxygen depth profiles for Lake Yankton generated from data collected at the deepwater ambient monitoring site during the summer months of 2006 and 2009.

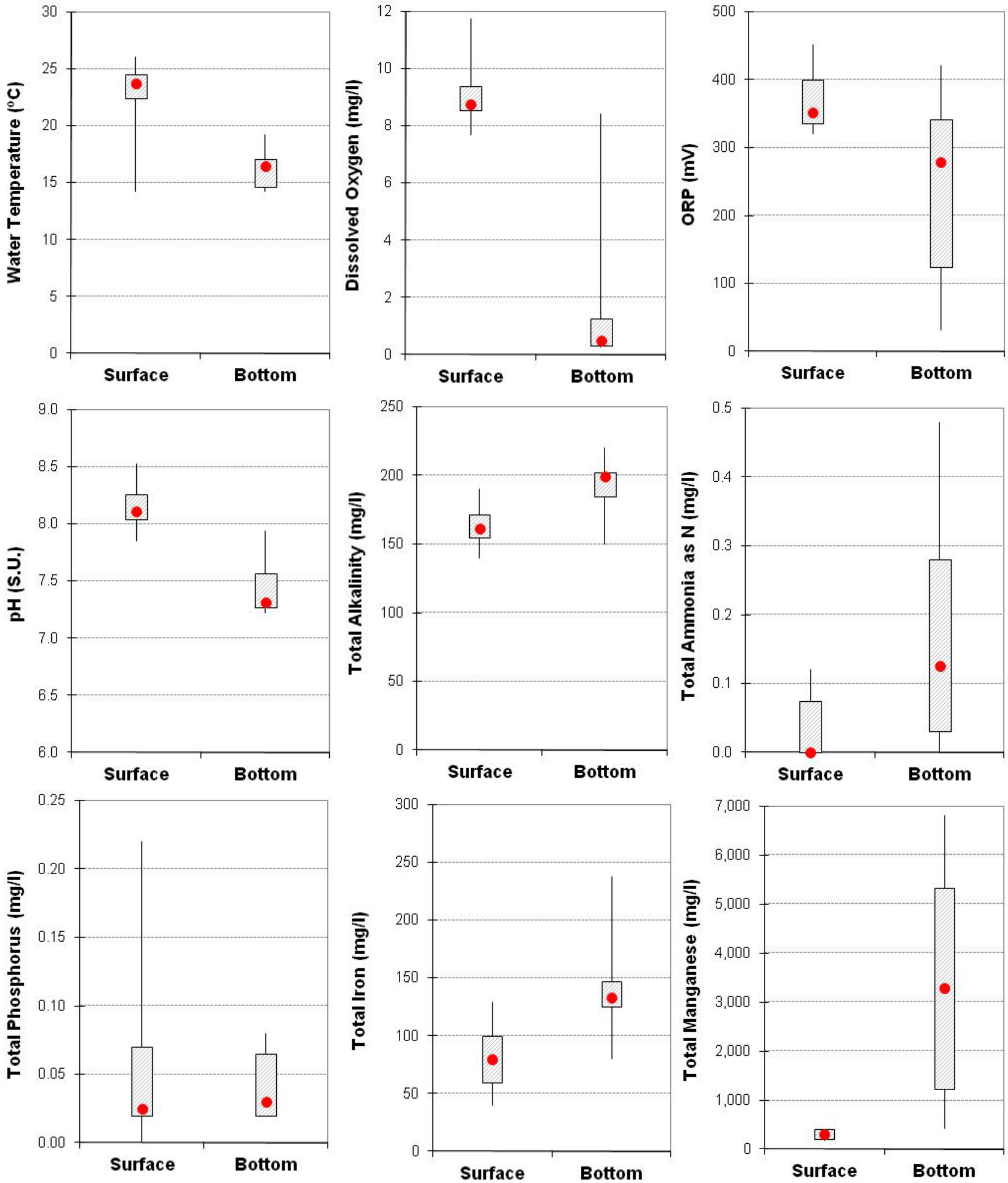


Plate 459. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total ammonia, total phosphorus, total iron, and total manganese measured in Lake Yankton at site YAKLKND1 during the summer months of 2006 and 2009.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

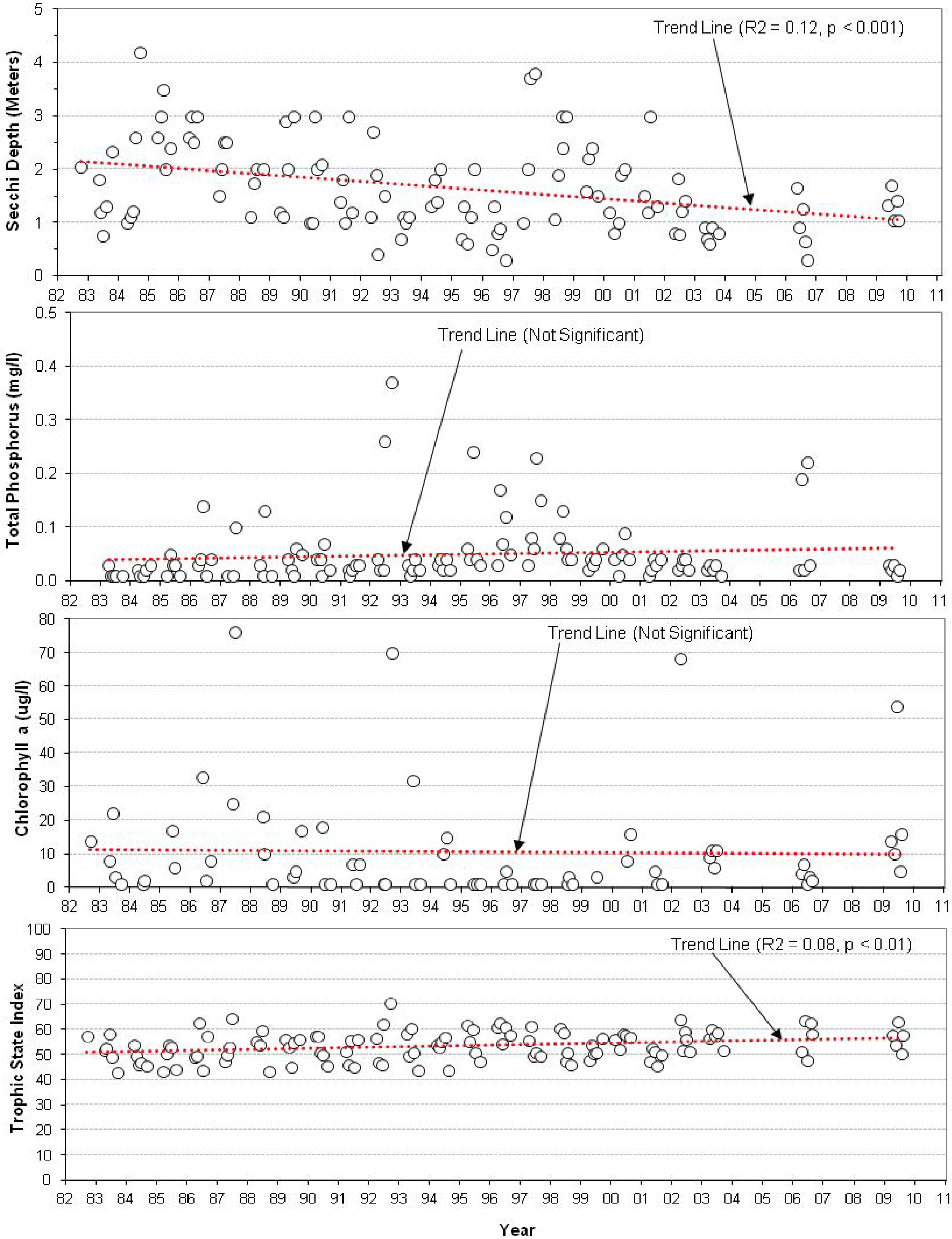


Plate 460. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Lake Yankton at the near-dam, ambient site over the 28-year period of 1982 through 2009.